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FRACTURES OF THE CARPAL SCAPHOID IN THE CANADIAN ARMY

A Review and Commentary

J. C. DICKISON, M.D., Captain, R.C.A., M.C., Westmont, Quebec, and
J. G. SHANNON, M.D., Major, R.C.A., M.C., St. Catherines, Ontario

THE fractured carpal scaphoid presents one of the most difficult and unsatisfactory problems in traumatic surgery. The basis of this problem would seem to be the appreciation of the various pathological lesions and the application of the proper treatment to them. In this presentation we give the results of a study of 257 cases of fractured carpal scaphoids occurring in a period of approximately 3 years in the Canadian Army Overseas. The system of central filing of all medical documents pertaining to each soldier ensures accurate statistics on each of the cases, and also accurate follow-up, in that recurrent complaints on any particular case, if present, would be encountered.

ANATOMY, MECHANICS OF FRACTURE, AND THE HEALING PROCESS

The proximal row of carpal bones consists of the scaphoid, the lunate, and the triquetrum. This proximal row has been well described as forming a segmented arch which is curved in two directions, convex on the radial and dorsal surfaces, and concave on the volar and midcarpal surfaces.

From the No. 1 Canadian General Hospital, Canadian Army Overseas.

The scaphoid or navicular bone is the most lateral in the proximal row of carpal bones. It lies against the concave distal surface of the radius, articulating with the radius above, the lunate and capitate on its medial side, and with the two multangulars on its distal surface. The internal structure of the scaphoid is cancellous in type. The features of its shape consist of a large gently concave medial surface for articulation with the head of the capitate, or os magnum; a prominent tubercle on its volar and distal aspect to which are attached strong ligaments, and a definite constriction about the center of the body, or the "waist" of the bone. Its radial and proximal surfaces together form a convex surface, the proximal three-fifths being covered with cartilage for articulation with the radius, the distal two-fifths, including the base of the tubercle, being extra-articular and providing attachment for ligaments. As mentioned before, the distal and medial surfaces are articular. A narrow volar and a wider dorsal surface are described, and both provide attachment for ligaments.

The ligamentous attachments to the scaphoid bear an important relation to the mechanics of fracture. First to be noted is that very

strong and dense ligaments, spreading out in a fan-like pattern, secure the distal half of the scaphoid to the two multangulars and to the capitate, bones of the distal row of the carpus. Similarly the proximal half of the bone has a very strong ligamentous attachment to the lunate. It will be realized that any strain placed on the midcarpal joint will also occur at the center or waist of the scaphoid bone. Indeed, the waist fracture of the scaphoid has been aptly called a continuation of the intercarpal joint line. Demonstration of these facts is clearly seen in the common type of fracture dislocation of the wrist,—the transscaphoid perisemilunar dislocation. Here the intercarpal joint is disrupted, the head of the capitate slipping dorsally "off" the lunate, fracturing the scaphoid and carrying with it the distal fragment. The lunate retains its position, and also its strong hold on the proximal fragment of the scaphoid, mainly on its radial and dorsal surfaces. The tendon of flexor pollicis longus fits snugly against the scaphoid, forming a sling or cradle for the bone. (1).

The frequency of nonunion in the fractured scaphoid has attracted thorough investigation of the blood supply. The vessels of supply enter through two main areas, via the ligaments about the tubercle, and those attached to the dorsal surface. Obletz and Halbstein, who examined 297 cadaver specimens, reported that in 13 per cent there were no arterial foramina proximal to the midwaist in 20 per cent there was a single small arterial foramen at the waist or proximal to it, while in 67 per cent there were 2 or more foramina proximal to the midwaist. These figures illustrate that the more proximal the fracture occurs, the more likelihood is there of a disturbance of the circulation to the proximal fragment. With these figures one might say that fracture through the midwaist may interrupt the blood supply in one-third of all cases.

Three types of fracture of the scaphoid are commonly described: fracture of the tubercle, fracture of the body, and the fracture dislocation. Fracture through the body of the bone is further differentiated into waist fracture and proximal pole fracture. Differentiation of these latter two by definition is difficult and, we feel, unnecessary. For this report we have classified as proximal pole fractures only those occurring in the upper third of the bone, and which are obviously not "waist" fractures. Fractures occurring just proximal to the waist, and which are dubious as to type, we have included in the group of waist fractures.

The tubercle fracture is an avulsion fracture caused by forced extension of the wrist in ulnar deviation. The lateral condensation of the radiocarpal ligament remains intact and tears off its attachment to the scaphoid, i.e. the tubercle. This fracture is extra-articular, and the blood supply to both fragments is always adequate.

The most common fracture is a transverse one through the body of the bone, usually occurring at the waist, or the center of the body. However, it may occur at any point in the proximal two-thirds of the bone. There are two points in the anatomy of the bone to favor fracture in the region of the waist; first, it is markedly constricted in this region, and, second, multiple blood vessels commonly enter about the waist on the dorsal surface.

The key to the understanding of the simple waist fracture is the consideration of the scaphoid as being the link or stay between the capitate, a bone of the distal row of the carpus, and the lunate, a bone of the proximal row. This theory has been recently re-emphasized (7). Any strain placed on the intercarpal joint will, of necessity, be transmitted to the waist of the scaphoid. When the wrist is not in forced dorsiflexion the relaxed ligaments prevent a concentration of force on any single bone (3). In a fall on the outstretched hand, however, which is the most common mechanism of injury, the wrist joint is most commonly forced into hyperextension and radial deviation. In this position the scaphoid is fixed in the concavity of the articular surface of the radius. It will be realized that once the scaphoid is fixed, by pressure of the distal carpals, any further movement at the intercarpal joint line will tend to "snap" the scaphoid. Todd, in 1921, very aptly called the common fracture of the scaphoid the "snapped waist" type (10).

The variation in location of the fracture is dependent upon the amount of radial deviation of the wrist during the impact. With ex-

treme radial deviation about two-thirds of the scaphoid is fixed between the capitate and the radius, and the fracture occurs in the region of the waist. With less deviation, diminution in the amount of similarly fixed scaphoid occurs, and the fracture occurs more proximally.

Bipartite scaphoids. In the early literature up to around 1930 there was considerable discussion in regard to whether a scaphoid in two parts was a fracture or a congenitally bipartite scaphoid. This question has now for some time been definitely settled. In this investigation only one case of bilateral congenitally bipartite scaphoids was found in checking the radiographic reports on nearly 1000 wrists.

The delaying effect of synovial fluid on the intra-articular fracture. Todd remarked that delay in union and nonunion might be attributed to the fracture line being constantly bathed in synovial fluid. There was considerable discussion on this problem for some time. The solution was generally accepted to be Johnson's investigation of the healing process in fractures of the scaphoid. He reported that no lytic action of synovial fluid was noted in his experiments, and that any delay can be ascribed to the healing mechanism itself. Kellogg Speed reported that synovial fluid is actually nutritive rather than harmful. In recent literature there is no support to the theory that synovial fluid may be a factor in delaying union.

The healing process. As stated, Johnson's excellent experimental work on this problem has been generally accepted throughout the literature. He found that lack of all periosteal callus is one of the main factors in causing slower fusion of the fragments into a solid mass. He also noted in his experimental dogs that the zone of reaction in the fractured scaphoid is extremely small in comparison to that in the radius, and extends only a few millimeters to each side of the fracture line.

STATISTICAL ANALYSIS

There were 257 cases in this series. The average age of patients in the whole group was 28 years; the average age of those with fresh fractures was 24 years. There were 124 fractures of the right side—49 per cent—and 133 of the left side—51 per cent. One hundred ninety-six, 75 per cent, involved the waist; 38 or 15 per cent involved the proximal pole; and 23 or 10 per cent involved the tubercule. Of the 196 waist fractures, the diagnosis was made within 1 week in 125 cases, within 1 to 5 weeks in 12 cases, later than 2 months in 47 cases. Fracture dislocations occurred in 11 cases. Early complete excision was done in 1 case.

Of the 38 proximal pole fractures, diagnosis was made within 1 week in 12 cases, within 1 to 5 weeks in 3 cases, and later than 2 months in 23 cases.

There were 23 fractures of the tubercle.

The Fracture with Early Diagnosis

Of the simple fresh waist fractures, or those treated within 1 week, the average time before immobilization was 1.4 days. There were 116 cases without displacement of fragments and all united. Of 6 cases with displacement of fragments 2 united and 4 did not. The remaining 3 cases in this group cannot be entered in the above classification because their roentgenograms were not obtainable for examination. From their histories it was gathered that in 1 case the scaphoid united, while the other 2 resulted in nonunion.

The average period of immobilization in the 116 cases which united was 88 days or 12.5 weeks. Ten per cent were healed in 2 months, 48 per cent in 3 months, 74 per cent in 4 months, 82 per cent in 5 months, 91 per cent in 6 months, and 100 per cent in 9 months. Twenty cases, or 17 per cent of this group, took more than 5 months to unite. An analysis of these cases showed that 12 of the 20 cases showed either avascular necrosis of the proximal fragment, unusual separation, or angulation of the fragments.

Of the 12 cases of simple fresh proximal pole fractures, those treated within 1 week, 8 united and 4 did not.

The average period of immobilization for the 8 cases which united was 143 days (20 weeks).

Histories of 4 cases which did not unite follow:

CASE 90. Sgmn. S., aged 26 years. Roentgenogram shows a separation of 3 millimeters at the radial margin of the fracture line, which was accepted. Wrist was kept in plaster for 6 months, with

resultant sclerosis of fracture margins and nonunion.

CASE 119. Pte. M., aged 22 years. Plaster-of-Paris cast kept on for 8 weeks, off for 1 week, on for 4 weeks, off 6 weeks, on again for 8 weeks. Result, nonunion.

CASE 3. Cpl. R. M., aged 21 years. This man removed his own plaster cast after 3 months and reported 7 months later with a painful wrist showing by x-ray an old ununited fracture.

CASE 128. Fus. M., aged 32 years, this man had his plaster cast removed at 7 weeks. He reported back 2 months later with a wrist showing marked disability and was put back in plaster again, without success in obtaining union.

Fractures of the tubercle. There were 23 patients in this group. Two patients underwent early excision of the fragment. One of these was returned to duty at 4 weeks, the other at 12 weeks after operation.

In 1 patient fracture was not united at 4 weeks when his plaster cast was removed. He was given a short course of physical therapy and sent to duty, and he has not reported difficulty in a follow-up of 1 year.

Of the 20 other cases, in 19 union occurred in on an average of 75 days or 11 weeks.

In the twentieth case the patient had his plaster cast removed at 6 weeks and no roentgenogram was taken at this time. Follow-up clinical examination after 1 year reported persistent pain and weakness in the wrist.

The Fracture Diagnosed between 1 and 5 Weeks

In this group there were 12 waist fractures and 3 proximal pole fractures. All of the waist fractures united. The average period before diagnosis was 3 weeks; the average period of immobilization, 92 days or 13 weeks. Two of the 3 proximal pole fractures united. A résumé of the third case follows:

CASE 239. Pte. D., aged 31 years. This man's fracture was diagnosed 2 weeks after injury, showed no displacement of fragments, was kept in plaster cast for 8 months, but did not unite.

Fracture Dislocations

There were 11 cases of fracture dislocation.

One man fell 60 feet and suffered a compound fracture dislocation with fractures of the scaphoid, styloid radius, styloid ulna, and head of the radius. He was returned to Canada 1 month after his injury.

There were 7 fracture dislocations of the transscaphoid perisemilunar type. In 3 of these an excellent reduction of the fragments of the scaphoid was obtained and they united in 6, 7 and 8 months, respectively. The 4 other cases of this type did not unite. In 3 of these the fragments of the scaphoid were not reduced.

There were 3 cases of fracture of the scaphoid associated with a volar dislocation of the semilunar:

CASE 163. L/Bdr. H., aged 25 years, was sent to Canada 4 months after injury with an associated fractured femur, and no roentgenograms were available for study.

CASE 237. Pte. C., aged 21 years, showed a marked displacement of the fragments of the scaphoid which was never reduced. He was kept in plaster cast for 5 months. At the end of this time there was a marked disability and his category was lowered.

CASE 101. Sgt. T., aged 24 years. A good reduction of the scaphoid fragments was obtained and wrist was kept in plaster cast for 10 months. At the end of this period, when roentgenograms showed the scaphoid still ununited, he was given a course of physical therapy and sent to full duties with minimal disability. He has not reported his wrist again in a follow-up period of 4 months.

The Fracture with Late Diagnosis

There were 70 cases of fracture with late diagnosis: of the waist, 47 or 67 per cent, of the proximal pole, 23 or 33 per cent, and of the tubercle, none. The period of time between injury and diagnosis was 2 to 6 months in 28 or 40 per cent; 6 to 12 months in 11 or 15 per cent; 1 to 2 years in 10 or 15 per cent; 2 to 5 years in 7 or 10 per cent; and more than 5 years in 14 or 20 per cent.

In this group 21 patients were left alone without treatment and of these 3 were recategorized; 27 were treated by immobilization and of these 10 were recategorized; 22 were treated by operation and of these 11 were recategorized.

As has been shown, in this group of 70 cases there were 24 in which the category of the patient was lowered, representing 80 per cent of the recategorizations in the full report.

The histories of 3 cases in the group of late diagnoses left alone without treatment and recategorization, follow:

CASE 89. Pte. B., aged 23 years. Diagnosis 1 year following injury: sent back to duty but boarded 2 months later with marked disability (C-1). Roent-

genogram showed proximal pole fracture—no displacement avascular necrosis of proximal fragment.

CASE 121. Cpl. B., aged 37 years. Diagnosis and recategorization to C-1 at 3½ years following injury; progressive weakness and pain since injury. Roentgenogram showed marked arthritis throughout carpus, cystic changes in fragments of scaphoid.

CASE 95. Pte. W., aged 33 years. Diagnosis at 13 months after injury; sent to duty as disability was only slight, returned 15 months later with marked disability subjectively and objectively, discharged from the Army Category E. Roentgenogram showed displacement, cystic changes in fragments of scaphoid, sclerosis of fracture margins.

Four patients were discharged from the Army for other reasons than their wrist condition; 3 of these were over 40 years of age when they reported their painful wrist and roentgenograms showed old ununited fractures with advanced arthritis of the carpus. Fourteen men of the group are carrying on full duties in the field.

In the group of cases with late diagnosis treated by immobilization there were 27 cases of which 6 united and 21 did not unite. In the ununited group 10 were recategorized.

Histories of the 6 cases that united follow:

CASE 125. Pte. B., aged 24 years. Waist fracture with no displacement, diagnosis at 2 months, united in 18 weeks.

CASE 159. Sgt. B., aged 30 years. Waist fracture with no displacement, diagnosis at 2 months, united in 15 weeks.

CASE 20. Pte. J., aged 22 years. Proximal pole fracture with no displacement, diagnosis at 6 months, union in 15 weeks.

CASE 113. Pte. H., aged 25 years. Waist fracture with no displacement, diagnosis at 6 months avascular necrosis of proximal fragment which is seen to be revascularizing, definite progression to union not complete at 20 weeks.

CASE 70. Pte. B., aged 20 years. Proximal pole fracture with no displacement, had immobilization for 6 months following original injury, then off for 6 months at the end of which he reported again with a painful wrist, plaster reapplied for another 9 months with resultant union.

CASE 35. Pte. B., aged 22 years. Proximal pole fracture with diagnosis 9 months after injury, kept in plaster for 9 months with resultant union.

For the study of the cases with late diagnoses treated by immobilization which did not unite, refer to Table I.

In the group of cases of ununited fractures treated by operation there were 30 cases. (This figure includes 8 cases of early diagnosis.) In this group 21 grafting operations were done with 9 recategorizations; 3 drilling operations with 1 recategorization; 4 complete excisions, all recategorized; 1 partial excision and 1 open reduction. The last 2 were not recategorized.

TABLE I.—20 LATE DIAGNOSED FRACTURES TREATED BY IMMOBILIZATION BUT DID NOT UNITE.

Case Age	Time before diagnosis	History of persistent trouble ever since original injury	Definite history of recent acute injury	Period of immobilization	Clinical result	Category lowered to	Follow-up period
92–27	3 yrs.	Yes	No	4 wks.	Poor	C-1	1 yr.
220–21	No. def. date	?	?	5 wks.	Good	No	2 yrs.
197–41	5 mos.	Yes	No	7 wks.	Poor	C-2	2 yrs.
86–32	2 mos.	Yes	No	8 wks.	Poor	B-2	1 yr.
155–20	1¾ yrs.	Yes	Yes	10 wks.	Good	No	2 yrs.
4–32	3 mos.	No	Yes	10 wks.	Good	No	2½ yrs.
43–26	1¼ yrs.	No	Yes	11 wks.	Good	No	10 mos.
136–45	15 yrs.	No	Yes	12 wks.	Good	No	7 mos.
100–27	3 yrs.	Yes	No	13 wks.	Poor	C-1	7 mos.
159–30	2 mos.	Yes	No	14 wks.	Good	No	1½ yrs.
194–25	10 mos.	No	Yes	14 wks.	Fair	C-1	1 yr.
6–38	No def. date	No	Yes	20 wks.	Fair	No	2 yrs.
72–22	No def. date	Yes	No	20 wks.	Good	No	1½ yrs.
122–24	5 mos.	Yes	No	20 wks.	Good	No	1 mo.
149–36	3 mos.	?	?	20 wks.	Good	No	2 yrs.
192–39	1½ yrs.	No	Yes	20 wks.	Poor	E	
118–21	1¼ yrs.	Yes	?	21 wks.	Poor	E	
82–30	9 yrs.	No	Yes	26 wks.	Poor	E	
87–31	5 mos.	?	?	32 wks.	Poor	C-2	1 yr.
73–20	6 mos.	?	?	40 wks.	Poor	E	

In the *grafting operation* group of 21 cases 8 united with 1 recategorized and 13 did not unite and of these 8 were recategorized.

Of the 8 cases that united, a graft was seen to be in good position in 6 cases. In the 2 other cases, roentgenograms taken within 2 weeks of operation show no evidence of a graft crossing the fracture line.

Of the 13 cases that did not unite, a graft was seen to be in good position in 6 cases, was seen in very poor position in 2 cases, and was not seen at all in 5 cases when there was still

TABLE II.—GRAFTING OPERATIONS

Case No. Age	Period between original injury and operation	Plaster before operation	X-ray arthritis	Appearance at time of operation				Graft in good position	Graft in poor position	Period of PPC after operation	United	No union	Category	Clinical result
				Sclerosis	Displacement	Necrosis of P.F.	Local vacuolation							
1 40	3 mos.	No	?	?	?	?	?	Yes		13 wks.		X	E	Poor
49 41	3 mos.	No	?	?	?	?	?	Yes		24 wks.		X	E	Poor
64 32	?	?	No	No	No	No	Yes	Yes		?	X			Good
65 32	5 mos.	10 wks.	No	Yes	Yes	No	No	No graft seen across fracture line 1 wk. postop.		21 wks.		X	C-2	Poor
116 29	5 yrs.	No	Yes	Yes	Yes	No	Yes	Yes		9 wks.		X		Graft repeated after 9 wks.
116 29	5 yrs.	Yes	Yes	Yes	Yes	No	Yes	Yes		20 wks.	X			Good
151 33	3 mos.	No	No	No	No	No	Yes	No graft seen across f. line 1 wk. postop.		33 wks.	X		B-2	Well united but def. arthritis and poor clinical result
174 20	1 yr.	6 wks	No	Yes	No	No	Yes	No graft seen at 3 mos.		26 wks.		X		Carrying on without reboard
175 43	6 yrs.	No	Yes	No	Yes	No	No	No graft seen across f. line 1 week postop.		12 wks.		X	C-2	Poor
176 24	1 yr.	No	No	No	No	No	Yes	Yes		15 wks.	X			Good
177 26	10 mos.	No	No	No	No	No	Yes	No graft seen across f. line 2 mo. postop.		9 wks.		X		Carrying on without reboard
178 22	4 mos.	No	No	No	No	No	Yes	No graft seen at 10 weeks		10 wks.		X	E	Poor
180 32	17 mos.	No	Yes	No	Yes	No	No	Yes		9 wks.		X		Carrying on without reboard
179 23	6 mos.	10 wks.	No	No	No	No	Yes	Yes		26 wks.	X			Good
203 21	5 yrs.	No	No	Yes	No	No	Yes	Yes		16 wks.		X		Operation repeated
203 21	5 yrs.	2d op'n	No	Yes	No	No	Yes	No	Yes	12 wks.		X	C-2	Poor
209 28	8 mos.	No	No	No	No	No	Yes	No graft seen across f. line 2 wks. postop.		14 wks.	X			Good
211 29	4 mos.	4 mos.	No	Yes	Yes	No	No	Yes		16 wks.	X			Good
213 34	11 mos.	No	No	No	No	No	No	Yes		28 wks.	X			Good
216 39	5 yrs.	6 mos.	No	No	No	Yes	Yes	Yes		10 wks.		X	C-2	Poor
221 26	6 mos.	2 mos.	No	Yes	Yes	No	No	No graft seen at 12 wks.		12 wks.		X	C-2	Poor

no demonstrable progress to union. (Postoperative times of these latter 5 roentgenograms: 1 week, 1 week, 2 weeks, 2 months, 3 months.)

Established arthritis of the carpus was noticed in the preoperative roentgenograms in 4 cases; in 3 the scaphoid did not unite.

In 6 cases there was a recorded history of the patient's reason for admission being a fresh injury to an old fracture. In 3 of these cases the original injury was 5 years old, and in 2 cases 1 year old. In none was union obtained, and in only 2 cases was a trial period of immobilization given before operation.

There were 8 cases in which the preoperative roentgenograms showed definite sclerosis of the fracture margins. Two of these cases united.

There were 7 cases in which the preoperative roentgenograms showed definite displacement of fragments. Two of these fractures united.

For further study of the grafting operations refer to Table II.

In the *drilling operations* group there were 3 cases with 2 united.

CASE 130. Tpr. T., aged 23 years. In this case there is revascularization of a "dead" proximal fragment in a most excellent manner. A waist fracture of the scaphoid was immobilized for 8 months following injury, at the end of which time a drilling operation was performed. Preoperative roentgenograms show that at this time the proximal fragment was one-third revascularized. Postoperative immobilization for a further 5 months did not cause any further revascularization, but there did follow solid union with good clinical result.

CASE 33. Lieut. W., aged 30 years. Waist fracture of the scaphoid with slight displacement, immobilized for 6 months following injury, at the end of which time a drilling operation was performed. Preoperative roentgenograms showed avascular necrosis of the proximal fragment and sclerosis of the fracture margins. Postoperative immobilization for a further 5 months resulted in x-ray union and a good clinical result.

CASE 12. Pte. B., aged 38 years. Diagnosis and drilling 15 months after injury. Roentgenograms showed a displacement (minimal) and no sclerosis nor vascular changes. Postoperative immobilization for 10 months resulted in failure to unite and a markedly disabled wrist.

In the *complete excision* group there were 4 cases and all were recategorized. Two cases were fracture dislocations with poor reduction of the scaphoid fragments. The 2 other cases were diagnosed at 8 months and 3 months, respectively, and both were operated upon at time of diagnosis. All patients showed poor clinical results following operation and were recategorized.

In the *partial excision* group there was 1 case.

CASE 114. Pte. T., aged 21 years. This was a transscaphoid perisemilunar dislocation in which the fragments of the scaphoid were not properly reduced. The proximal fragment was excised after 10 weeks of immobilization. He was returned to full duties 5 weeks later with an excellent immediate result.

In 1 case *open reduction* was done.

CASE 144. Spr. R., aged 22 years. Diagnosis 5 months following injury. An open reduction operation was performed at this time. Roentgenograms taken 1 month following the operation show a marked displacement still present and no evidence of union. He was sent to full duties 3 months later, and no further roentgenograms were obtained. He has not reported his wrist again in a period of 2 years.

Displacement

In the 125 cases of fracture with early diagnosis there were 8 displacements or 6 per cent. In the 70 cases of fracture with late diagnosis there were 36 displacements or 50 per cent.

In 6 of the 8 cases of fresh fracture with displacement the scaphoid did not unite.

In the fractures with late diagnosis, 19 of the 24 recategorizations showed displacement of fragments.

Arthritis

In the group of cases with late diagnoses showing x-ray evidence of established arthritis of the carpus at the time of diagnosis, there were 18 or 30 per cent. Of these 7 were left alone without treatment, their average age was 41 years, and 1 was recategorized. Another 7 patients were treated by immobilization, their average age was 31 years and 4 were recategorized. Four others were treated by operation, their average age was 35 years, and 2 were recategorized.

Avascular Necrosis

Avascular necrosis of the proximal fragment was seen in 7 of the cases with late diagnoses, 10 per cent.

An exact figure of the occurrence of this complication in the fractures with early diagnosis cannot be given.

Sclerosis of Fracture Margins

Sclerosis of the fracture margins was seen in 16 of the series of cases with late diagnoses (ca, 25 per cent). In 11 of these cases the fracture was 1 year old or more when the diagnosis was made, while in the other 5 cases the fracture was less than 6 months old.

That sclerosis of the fracture margins can occur within 4 months may be illustrated by this case:

CASE 211. Lieut. D., aged 29 years. Waist fracture, plaster applied on day of injury, a displacement was present which was not corrected, roentgenogram at 4 months shows the same displacement, no evidence of union, and definite sclerosis of the fracture margins.

Six of these underwent grafting operations, and 2 of these united.

Three were treated by immobilization. In none was union obtained. All 3 were poor clinical results and were recategorized.

Two patients left alone, aged 52 and 43 years, were discharged from the Army for other conditions, with their wrists being mentioned as moderately disabling.

Five others left alone have been carrying on with full duties.

Cystic Changes

Local vacuolation. This process is interpreted as an extension of the local resorptive process at the fracture line. This extension takes a circular expanding form and shows on the roentgenogram as incomplete circular areas of rarefaction with their bases at the fracture line. In the cases with late diagnoses this picture in the roentgenograms could be discerned in about 40 per cent of cases.

Cystic degeneration involving the whole of the distal fragment was seen in 3 cases.

The process of cystic change was not seen in the proximal fragment except locally at the site of fracture. It was seen with and without the definite picture of sclerosis of the fracture margins. It was seen at an early date (4 months after injury) and also at a late date (5 years after injury). Bone union was obtained in 5 cases of the 12 showing this condition.

Associated Injuries

It was noted that associated carpal injuries were extremely rare, being present in only 5 per cent of all cases.

In reviewing the histories it was noted that the question of associated injuries had no relation to the union of the fractured scaphoid, except of course in the fracture dislocations.

In the following tabulation the associated injuries to the same extremity are listed, excluding the fracture dislocations which are recorded elsewhere: fracture of triquetrum, 6 (in 5 cases an avulsion chip fracture off dorsum); fracture of head of radius, 4; fracture of capitate, 3; fracture of styloid radius, 3; fracture of shaft of radius, 2; fracture of styloid ulna, 2; fracture of hamate, 1; Bennett's fracture, 1; dorsal dislocation of distal ulna, 1; fracture of humerus (supracondylar), 1; fracture of humerus (shaft), 1; fracture of clavicle, 1; gunshot wound of hypothenar eminence, 1.

Recategorization

A list of the cases which required recategorization is given in Table III.

TABLE III.

Grade	Total	Fresh with displacement to nonunion	Old: no treatment	Old: immobilization	Old: operation	Fracture dislocations
B-2	1			1		
C-1	9	1	2	4	2	
C-2	10	1		1	6	2
E	10		1	4	3	2
Total	30	2	3	10	11	4

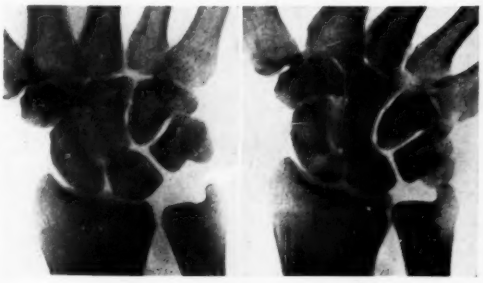
ANALYSIS OF STUDY

We have presented a review of 257 cases of fractured carpal scaphoids. The results of treatment in those cases diagnosed early are quite satisfactory, in the main, but there are certain problems still presented by this group of cases which demand our earnest attention. In the cases not diagnosed early the results of treatment leave much to be desired. This is not a criticism of those handling the cases, but rather an indication of our faulty and confused knowledge of the essential problems of this particular fracture.

The results achieved in the treatment of the simple fresh waist fractures were excellent. Union occurred in all these cases. If such fractures are immediately immobilized and kept so for a sufficient length of time they will unite. The figures in this report and the impressions gathered from a review of the literature offer firm support to Boehler, Schnek, and Soto Hall, in the statement that by far the majority of fractures of the carpal scaphoid, if properly immobilized within a week, will unite without undue delay and will cause

no further concern. Boehler and Schnek both go so far as to say that one can expect 100 per cent union, while Soto Hall states that over 90 per cent perfect results may be expected. In this series of 116 cases treated early and well, all cases resulted in union. The problem does not lie in the treatment, but rather in the diagnosis—indeed the major problems from fractured scaphoids arise from failure to make an early diagnosis.

A fractured scaphoid may be suspected from clinical examination, but the diagnosis can be positively established or excluded only by roentgenograms. The latter must be taken in the anteroposterior, lateral, and oblique positions. The oblique is the most important view, and frequently several roentgenograms in the oblique position are necessary to bring the fracture line into view. It must be kept in mind that immediately after injury it is often difficult to establish the diagnosis roentgenographically. Only a very faint fracture line may be seen, as in Figure 1. To overlook such a faint line is to court disaster, as this case plainly shows. The same is true of the case in which a fracture is suspected from clinical examination but cannot be demonstrated by roentgenograms (Fig. 2). Such injuries must be treated as fractures until repeated roentgenograms in 2 to 3 weeks' time enable one to determine definitely whether or not there is a fracture present. Failure to take these precautions will lead to the fracture being treated as a sprained wrist. In this series 18 of the 70 cases with late diagnoses were treated originally as sprained wrists. This is a very serious error and must be corrected. The diagnosis of sprained wrist should be made with the greatest of caution, and only after fracture of the scaphoid has been positively excluded by repeated roentgenographic examinations.



a b

Fig. 1. Case 227, Pte. R., aged 22 years. a, Roentgenological appearance on the day of injury. There is a faint line in the proximal pole which was not noticed. A diagnosis of sprained wrist was made and the man was returned to duties. He came back 3 months later with persistent complaints about his wrist, and roentgenogram b was taken. A grafting operation at this time was unsuccessful. He was then under persistent medical treatment for 1½ years, at the end of which time he was discharged from the Army with the psychiatric diagnosis "reactive depression."

In this series there are 125 simple waist fractures that were diagnosed early. In only

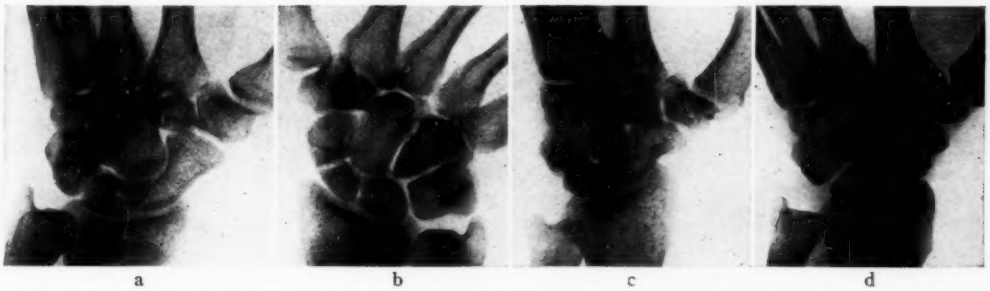


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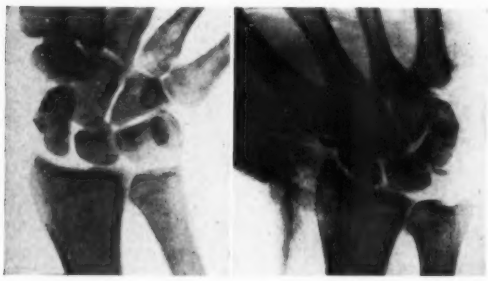
Fig. 2. Case 53, Gnr. L., aged 24 years. a, Roentgenogram taken on the day of injury, which was considered negative for fracture. There is a faint but definite line through the waist of the bone. b, Roentgenological appearance 7 months later when he returned with the history of persistent complaints about his wrist. As the disability was not marked this patient was not told of his fracture and was returned to full duties. In a follow-up period of 8 months he has not reported his wrist again. c, Roentgenogram, Case 104, Pte. P., aged 25 years, taken shortly after injury which was declared negative for fracture. There is noticeable a faint line at the radial side of the waist. The patient was returned to duties. d, the same case 8 months later when he returned complaining of persistent pain and weakness in his wrist. His wrist was immobilized for 3 months, at which time there was no demonstrable progress toward union and he was returned to duties with a lowered category.

a b

Fig. 3. Case 211, Lieut. M., aged 29 years. a, Roentgenogram taken on day of injury, showing a displacement in the form of lateral deviation, which was not corrected. b, After 4 months of immobilization this roentgenogram was taken and showed the same displacement, with sclerosis of the fracture margins,—nonunion.

Fig. 4. Case 110, Gnr. A., aged 25 years. This wrist was immobilized in plaster the day after injury. The roentgenogram was taken 2 months later and showed clearly a displacement of the fragments in the form of angulation, with considerable separation at the radial margin of the fracture line. Nine months after injury, at the time this report was made, he is still in plaster. This wrist also shows a fracture of the ulnar styloid.

6 of these was there displacement, and 4 of these developed nonunion. Displacement is a rare but serious complication and must be corrected. It may be a lateral deviation (Fig. 3), a distraction of the fragments, or an angulation (Fig. 4), this last usually being a widening of the radial side of the fracture line. The wrist must be manipulated with a view to closing any gap that exists between the fragments, and Soto Hall's description of a proper reduction and the means of attaining it cannot be improved upon. Simply described, this is dorsiflexion in radial deviation and impingement of the fragments by the greater multangular using the thumb as a lever (Fig. 5). Of course, if there is marked irreducible displacement of a fragment, or comminution with irreducible displacement, this is a different problem and is best handled by early operative removal of the displaced fragment or fragments, before reactive hypertrophic changes are set up in the carpus.



a b

Fig. 5. Gnr. W., aged 27 years. These two roentgenograms were taken while the patient was under general anesthesia and demonstrate clearly the effect upon the fracture of forced radial deviation extension, and abduction of the thumb. a, Forced ulnar deviation; b, forced radial deviation.

When the proximal pole fractures which were diagnosed early are examined, three points stand out: First, there were only 12 of these as compared with 125 waist fractures. Second, the average time required for union was 20 weeks, whereas in the waist fractures it was 12.5 weeks. Third, delayed union and nonunion occurred relatively much more often in this group than in the waist fractures. It has been pointed out that in fractures of the proximal pole vascular disturbances are more common than in fractures in other parts of the bone, and frequently complete severance of the blood supply to the proximal fragment may occur, leading to avascular necrosis of this portion of the bone. It is therefore to be expected that these fractures will take longer to unite than those of the waist, a point which is even more apparent when displacement of the fragments is present. Avascular necrosis is not necessarily a precursor of nonunion,—it only delays union. Revascularization of the proximal fragment with

a b c

Fig. 6. Case 130, Tpr. T., aged 23 years. a, Roentgenogram taken 3 months after injury. The wrist was immobilized on the day of injury. Avascular necrosis of the proximal fragment is seen. b, 10 weeks later, and after a total period of 24 weeks' immobilization. The proximal fragment is seen to be about one-third revascularized, and the fracture is uniting. Two months after this roentgenogram was taken a drilling operation was performed. c, Roentgenogram taken 5 months after drilling shows the fracture united. Following the drilling operation the proximal fragment did not revascularize any further. The patient's wrist had a total period of immobilization of 12 months. Clinically good result.

subsequent union of the fracture is clearly demonstrated by the case illustrated in Figure 6. But it should be noted that this took 12 months. From an examination of the cases in this group which did not unite it would seem that these points are not sufficiently appreciated. Displacement was not reduced, and uninterrupted fixation was not persisted in until union was obtained.

Fig. 7. Case 82, Rfmn. B., aged 30 years. This roentgenogram was taken at the time of diagnosis, 8 years following injury. He had had a recent fresh injury which caused him to report. His wrist was now immobilized for 27 weeks, at the end of which time he presented the picture of Sudeck's atrophy of the carpus, with marked disability; dependent cyanosis, advanced muscular atrophy, and marked limitation of all movements of the wrist. He was at this time discharged from the Army as unfit for any duties, on the basis of his wrist condition.

No matter how astute the medical profession may become in diagnosing fractured scaphoids early, the late cases will always be present. Often the original symptoms are so mild that the patient pays little attention to them, and it is not until months have passed, with gradually increasing pain and disability, that medical aid is sought. At times the original symptoms may entirely disappear, and it is not until a second injury has caused symptoms that the patient seeks medical advice. In this report there are 70 such cases—cases

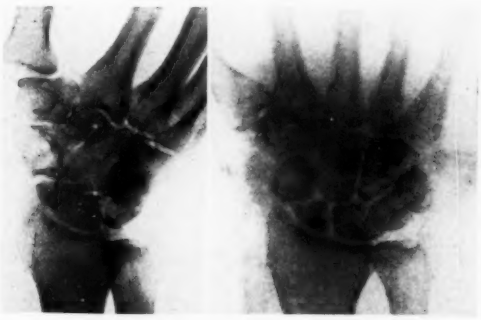


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Fig. 8. Case 4, Gnr. McL., aged 32 years. a, This roentgenogram was taken at the time of diagnosis showing an old fracture with established nonunion and advanced cystic changes in the distal fragment. His wrist was immobilized in an attempt to gain union. At the end of 10 weeks this treatment was discontinued and the patient was returned to duties. In a follow-up period of 1 year he has not reported his wrist again. b, The same wrist in plaster.

Fig. 9. Case 213, Pte. M., aged 34 years. This roentgenogram was taken at the time of diagnosis, 11 months after injury. It shows no displacement and no sclerosis of fracture margins. His scaphoid was grafted at this time, and with postoperative immobilization for 6 months the scaphoid united soundly.

that were not diagnosed until at least 2 months after the injury. From a scrutiny of the "Statistical Analysis" of this group, it is apparent that these cases gave rise to great difficulty in treatment, that there was considerable variety in the methods of treatment, and that the result of the treatment was frequently disappointing.

In this same analysis it is seen that the cases fall into three groups, namely: those who received no treatment, those who were treated by immobilization, and those who were treated by operation. It must be pointed out that this division is not formed on a pathological basis, but rather on varying idiosyncrasies of the surgeons who happened to be treating the cases. In one instance a patient would be returned to duty, with or without his category being lowered, depending upon the severity of the symptoms, while in another instance a like case would be either immobilized or subjected to an operative procedure. From a study of this series it is impossible for us to say what is the best treatment in a given case, but we are of the opinion that a careful examination of this group does lead to a better appreciation of the problems concerned in this type of case.

Twenty of the cases in this group with late diagnoses were not treated. In cases in which the symptoms were marked patients were recategorized according to their disability and were sent back to duty. Fourteen of these 20 cases were able to return to full duties without recategorization. What the final result of this disposition of these 14 cases will be we cannot say. Up to the time this survey was made none of these patients had reported further trouble with their wrists. Whether a case of fractured scaphoid can carry on indefinitely with no great disability we cannot say. It seems possible that a fracture without displacement or vascular changes might not give

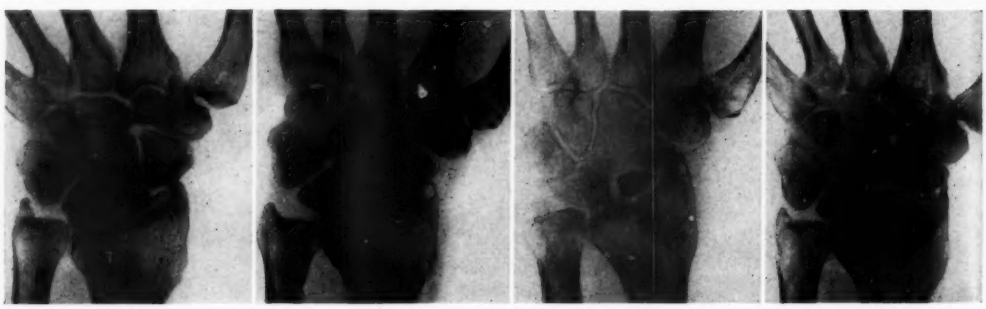

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Fig. 10. Case 175, Gnr. M., aged 43 years. a, Roentgenogram taken at the time of diagnosis, 6 years following injury. A grafting operation was performed at this time. b, Roentgenogram taken 8 days after the operation. There is a marked increase in displacement of the fragments. c, Roentgenogram taken 8 weeks after operation, showing marked decalcification throughout the carpus except for the proximal fragment of the scaphoid, which demonstrates avascular necrosis. d, Immobilization after operation was discontinued after 3 months, and the patient was returned to duties. He reported back 4 months later, complaining of severe pain and disability, and roentgenogram d was taken at this time. There is no evidence of union; his carpus has recalcified and the proximal fragment of the scaphoid has revascularized; there is radiological evidence of artbritis throughout the carpus.

a b

Fig. 11. Case 195, Tpr. B., aged 23 years. a and b, Transscaphoid perisemilunar dislocation of the wrist, with associated fracture of the triquetrum. These two roentgenograms illustrate the relationship of the proximal fragment of the scaphoid with the semilunar, and the distal fragment with the capitate, as discussed in the text.

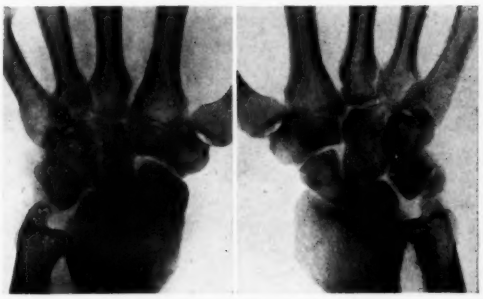

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Fig. 12. Case 78, Spr. F., aged 43 years. a and b, Left and right wrists for comparison. This man injured his left wrist 12 years ago. He has noticed it to be somewhat weak at times, but it was never particularly troublesome. In the past few months, however, he has noticed steadily increasing pain and weakness, and he was sent to hospital for investigation. There was evident marked weakness of grip and about 50 per cent limitation of both flexion and extension of the wrist. He was considered unfit for any duties in the Army and was discharged on the basis of arthritis of the wrist.

rise to symptoms after the initial injury has subsided. In this series we have found several patients who have carried on for varying periods up to 15 years without any appreciable complaints, and have reported only after they sustained a second injury to their wrist. On the other hand it seems reasonable to assume that if a wrist seen a few months after the fracture has occurred shows much displacement or vascular changes, ultimately arthritis will develop and the disability will be severe, even though at the time first seen the symptoms may be quite mild.

Twenty-seven patients in this group with late diagnoses were treated by immobilization, but in only 6 of these did union occur. The question immediately arises,—why did the others not unite? This question can be answered only partially. It is unreasonable to expect that a fracture showing sclerosis of the margins would unite by merely being immobilized, yet such fractures were treated in this way (Figs. 7 and 8). As pointed out in relation to the fresh fracture, avascular necrosis delays union, but does not cause nonunion, and, if such a fracture is treated by immobilization, the treatment must be carried on without interruption until union is obtained, even though this may mean a period of a year or more. Some writers claim that an old fractured scaphoid will unite if immobilized long enough, provided there is not established nonunion. If this is true then some of these fractures that did not unite were not immobilized for a sufficient period. We are unable to comment on this statement, but it is interesting to note that no fracture united in which diagnosis was made later than 9 months after the injury, and also that the fractures in which immobilization was persisted in for the longest periods without success gave the poorest results when treatment was discontinued (Table II).

The bone grafting operation was performed in 21 cases, 2 patients having 2 grafting operations. Union was obtained in 8 cases. Examination of Table II shows that there is a great deal of confusion in the minds of the surgeons as to the purpose of the operation. Indeed, in many of the cases one wonders why it was performed. In only 7 patients is there evidence of established nonunion,—sclerosis of the fracture margins, and union was obtained in only 2 of these. It is therefore in these 2 cases alone that one can credit the operation with having had a beneficial effect. In 7 cases of the group a period of immobilization with plaster was tried before operation, but in 5 of these sclerosis was present. As pointed out, it is useless to expect such treatment to have any effect. In any evaluation of results of operative procedures the postoperative period of immobilization must be carefully consid-

ered (Fig. 9). In the fractures that united following operation, 14 weeks is the shortest period of immobilization; while in those that did not unite their plaster was often removed in less than 14 weeks. The operation was performed on 4 cases with demonstrable arthritis of the carpus. One of these 4 united, but the clinical result was poor and necessitated recategorization. Two of the grafting operations resulted only in marked increase in the displacement of the fragments (Fig. 10). There were two grafting operations in which the procedure incited the development of avascular necrosis of the proximal fragment. In one of these cases revascularization occurred.

Clarification of the indications for the use of this operation is imperative. There is only one proven indication for its use, and that is established nonunion—sclerosis of the fracture margins. So far as we can learn there is no reason to suppose that a bone graft will shorten the period required for a fractured scaphoid to unite, and unless evidence of such is forthcoming the operation should never be performed for that purpose. The technical difficulties of the operation are great, and it should be undertaken only after most serious consideration.

The drilling operation was done in 3 cases. Sclerosis was not present in any of these, and in 1 case the operation was performed after an avascular fragment had shown definite evidence of revascularization. Five complete excisions were performed. In 1 case the scaphoid was excised within 2 weeks of injury for a displacement which could not be corrected. This man showed an excellent result in a follow-up of 6 months after his return to full duties. In the other 4 cases excision was done late, and the results were uniformly poor. One excision of a proximal fragment done early gave a good result.

There were 11 cases of fracture dislocation in this series: 1 severe compound fracture dislocation, 7 typical transscaphoid perisemilunar dislocations, and 3 fractured scaphoids associated with a volar dislocation of the semilunar. In all these cases the proximal fragment of the scaphoid retained its relationship with the semilunar, and the distal fragment with the capitate. This relationship is constant, and the reason for it has been pointed out in the anatomical description of this report (Fig. 11). These fractures are, of course, seen early, and once the dislocation has been reduced the problem, so far as the scaphoid is concerned, is that of the simple fresh fracture.

In summing up this study of 257 cases of fractured scaphoids, certain positive points stand out. These are not new,—they have been pointed out by many writers before, but surely they need re-emphasis. There are apparent, however, certain unsolved problems regarding this fracture to which we would draw attention.

The primary problem in this fracture is early diagnosis. With careful clinical and roentgenological examination, repeated if necessary, the diagnosis should not be missed. The fractured scaphoid diagnosed early and properly treated will almost invariably unite. By proper treatment is meant reduction of displacement, if present, and uninterrupted immobilization with the wrist in extension and radial deviation until union occurs. Roentgenographic examinations must be made during the course of treatment. The plaster should be removed only for the few moments required to take the roentgenogram, and the surgeon should handle the wrist during this time to ensure that no disturbance of the fracture occurs.

Avascular necrosis may occur in the proximal fragment. This will delay union but will not necessarily cause nonunion. With uninterrupted immobilization, revascularization will likely occur and union take place. Whether or not multiple drill holes will hasten the revascularization of such a fragment, and thus shorten the period required for union, we cannot say from the evidence of this study. In 1 case the drilling operation effected the cessation of revascularization of a proximal fragment when this was one-third completed.

The fractured scaphoid diagnosed late is a very difficult problem. It is probably true that a fractured scaphoid never unites if left untreated. Will such a fracture if left untreated invariably lead to a painful wrist in later life? We have shown that in some such cases patients carry on for long periods with only a minimum of discomfort. We have also shown that some are symptom free for a long

period, and when injured a second time their symptoms are relieved by a short period of immobilization, and that they are again able to carry on for considerable periods symptom free. But these are people in the third and fourth decades of life. What will happen to them in the fifth decade? That question we are unable to answer either from this study or from a perusal of the literature. That some of them develop marked disability in later life is undoubtedly true (Fig. 12), but if others may go through life with no significant disability then we must learn to select those that will not develop symptoms from those that will.

How to obtain union consistently in these late diagnosed fractures within a reasonable time is still an unsolved problem. Immobilization was often unsuccessful in the cases presented in this report. The criticism might be made that the immobilization was not carried on long enough. This may be true, but we would point out the apparent danger of persisting in this form of treatment too long without evidence of progress toward union. Complete or partial excision is of no use in these fractures. Unless this operation is carried out soon after the fracture occurs the results will be uniformly poor. The drilling procedure may be of help in nonunion, but we can form no opinion from this study. If nonunion becomes established, union may be obtained by a grafting operation. This is, however, a difficult operation, and a technique has not yet been devised that offers reasonable hope of success.

The late fracture with degenerative arthritis is an arthritis problem, and must be treated as such. Union of the fracture will not relieve the symptoms, and palliative treatment is all that can be offered,—fusion of the wrist being the last resort of the surgeon, and warranted only by severe disability.

Finally we would point out that the period required for healing in any fractured scaphoid may be very long. The patient may be able to carry on his occupation while undergoing treatment. Often, however, this is impossible, in which case there is a serious economic loss. We have no suggestions for shortening this period, but we would point it out as another problem facing all surgeons who treat this fracture.

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For a most complete set of references on the subject refer to an article by Thorndike and Garrey in the N. England M. J., 1940, 222: 827.

CALCIUM CHANGES IN ACUTE PANCREATIC NECROSIS

HUGH A. EDMONDSON, M.D., Los Angeles, California, and
CLARENCE J. BERNE, M.D., F.A.C.S., Major, M.C., U.S. Army

THE predominant regional effects of acute pancreatic necrosis are dependent upon the action of damaging concentrations of escaped pancreatic enzymes. The purely chemical nature of the tissue injury creates almost unique effects. This is dependent upon the reaction of lipase and fatty tissues. In 1882 Balser applied the name "fat necrosis" to the gross chalky lesions occurring locally as a result of acute pancreatic necrosis. Eight years later R. Langerhans demonstrated that these lesions were the result of the reaction of lipase on neutral fat. He applied the discoveries of Claude Bernard who had identified pancreatic lipase and demonstrated its capacity to split neutral fat into fatty acids and glycerol. Fundamentally, Langerhans showed that lesions of fat necrosis consisted of calcium soaps resulting from the enzymatic effect on neutral fats. He further showed that the glycerol by-product was absorbed without recognizable effect. Logical consideration of the quantitative factors involved would suggest that systemic effects might follow the dislocation of large amounts of calcium from the blood stream into the areas of fat necrosis.

Normal physiology of calcium balance in the body fluids is such that a normal total blood calcium is usually considered to vary from 9 to 11 milligrams per 100 cubic centimeters of blood although in a large series of adults Robertson found it not to fall below 9.9 milligrams. Two roughly equal fractions of serum calcium exist. One half is combined with protein and constitutes the nondiffusible fraction. The combined calcium probably acts as a homeostatic reservoir contracting under conditions tending to deplete the diffusible calcium. However, the amount of available combined calcium may be diminished due to plasma loss in shock states. Another reservoir to maintain the diffusible calcium exists in the interstitial fluid and bone. The functional activity of this mechanism possibly is impaired in shock states.

The second half of the blood calcium is not combined and is in the diffusible state, mostly ionized. This is the fraction which, if reduced, produces physiologic effects, and further it constitutes the source of calcium which is chemically available for combination with fatty acids in the formation of calcium soaps. In the normal adult of average weight the sum of these two fractions which is found in the total circulating blood is 650 to 700 milligrams of calcium.

The observation of a patient with fatal acute pancreatic necrosis in whom tetany existed with normal blood carbon dioxide combining power (H. E.) led to quantitative determinations of blood and tissue calciums which furnish the data upon which this report is based.

MATERIALS AND METHODS

For the investigation of the three phases of possible calcium disturbance mentioned in the previous discussion we have utilized a group of patients seen at the Los Angeles County Hospital between January, 1940, and October, 1943.

One group of observations consists of estimations of the total amount of calcium deposited in and around the pancreas in patients upon whom necropsy was done following death from acute pancreatic necrosis. In some cases an inaccurate antemortem diagnosis had been made and, therefore, other calcium studies had not been done.

A second group of observations consists of measurements of the total blood calcium on patients with acute pancreatic necrosis and a third group consists of measurements of diffusible and nondiffusible calcium in patients who were known to have lowered total serum calcium.

Aided by grant from the Michael J. Connell Fund.
From the Departments of Pathology and Surgery, School of Medicine, University of Southern California, and the Laboratory of the Los Angeles County Hospital.

The following procedures were used in making the determinations.[1] A number of check observations with an outside laboratory agreed with the findings as recorded.

Method for calcium on tissues. Five or 10 grams of the tissue are weighed out in a platinum or silica dish and dried at 120 degrees C. overnight to remove most of the moisture. The samples are then ashed in a muffle at 500 to 600 degrees C. until all the carbon is gone and only white ash remains.

After cooling, the ash is dissolved in 3 to 5 cubic centimeters of tenth normal hydrochloric acid, heated to boiling and the solution filtered into a 50 cubic centimeter graduated centrifuge tube. Four extractions with hydrochloric acid are made, filtering each successive portion into the centrifuge tube. Enough tenth normal hydrochloric acid is then added to each tube to make a volume of 15 or 20 cubic centimeters in order to have a constant volume for all samples. The hydrochloric acid is then neutralized with dilute ammonia to a *p*H of 5.0, nitrazine paper being used as an indicator. A blank made of 15 or 20 cubic centimeters of tenth normal hydrochloric acid and neutralized with dilute ammonia will give one a fairly accurate estimate of the amount of ammonia to use. The final volume is noted after neutralization. Saturated ammonium oxalate is added in the proportion of 1 cubic centimeter for every 5 cubic centimeters of solution present. The solution is allowed to stand 4 hours, preferably over night.

It is centrifuged for 15 to 20 minutes at 3000 to 3500 revolutions per minute. The solution is decanted and allowed to drain for a few minutes. The sides of the tube and the precipitate are washed with 5 cubic centimeters of 2 per cent ammonia that has been saturated with calcium oxalate and then filtered. The tube is shaken thoroughly in order to break up the mat at the bottom. It is then centrifuged, decanted, and washed again. After the second washing, the precipitate is dissolved in an excess of fiftieth normal ceric ammonium sulfate—usually 10 cubic centimeters is sufficient. Two cubic centimeters normal sulfuric acid is added for each 10 cubic centimeters of ceric ammonium sulfate used. The tubes are heated in a boiling water bath for 5 to 10 minutes until solution is complete. The solution is cooled and back-titrated with fiftieth normal ferrous ammonium sulfate, orthophenanthroline being used as an indicator. Two to 3 drops of a 0.025 molar solution is sufficient. The color changes from pale blue to red and the end point is very sharp. (Tenth normal solutions of the reagents named are prepared and diluted to fiftieth normal just before use.)

A blank determination is run, 10 cubic centimeters of fiftieth normal ceric ammonium sulfate, 2 cubic centimeters of normal sulfuric acid, and 2 to 3 drops of orthophenanthroline and titrate with fiftieth normal ferrous ammonium sulfate being used. The calculation of the amount of calcium present is made as follows:

Blank—back titration of sample—Y or the number of c.c. of 0.02N ceric ammonium sulfate reacting with the calcium present.

1 c.c. of 0.02N ceric ammonium sulfate is equivalent to 0.4 mgm. calcium.

$$\frac{0.4 \times Y \times 100}{\text{grams of tissue in sample}} = \text{mgm. of calcium per 100 gm. of tissue (wet).}$$

Calcium determination—serum: Two cubic centimeters of serum are diluted with an equal volume of water and the calcium precipitated by 1 cubic centimeter of saturated ammonium oxalate. After complete precipitation, the calcium oxalate is separated by centrifuging and is then washed twice with 2 per cent ammonium hydroxide—saturated with calcium oxalate.

The oxalate is then determined by oxidation with a slight excess of ceric sulfate, the excess being determined by back titration with ferrous sulfate, microchemical titration procedures being used. The procedure is essentially that which was described by Larson and Greenburg.[2]

Diffusible calcium. An ultrafiltrate of serum is prepared by means of a cellophane No. 300 film, in a special filtering apparatus under about 50 pounds per square inch pressure. The ultrafiltrate is treated with ammonium oxalate and the calcium precipitated and determined in the same manner as serum calcium. By using smaller quantities of reagents,

[1]Done with the assistance and supervision of Albert C. Chaney, Ph.D.

[2]J. Biol. Chem., 1938, 123:199.

etc., as small an amount as 0.5 cubic centimeter of ultrafiltrate may be used.

Tissue calcium. The most accurate technically feasible index to the magnitude of the calcium disturbance in acute pancreatic necrosis is the measurement of total calcium in the calcium soaps formed in and around the pancreas when necropsy makes this possible. In addition to this amount there is possibly a further similar displacement elsewhere in the body because of the known high blood lipase levels and the known presence of subcutaneous fat necrosis in some cases. Another factor in estimation of the displaced calcium is the normal calcium content of the pancreas and surrounding tissue.

The results of quantitative analysis of tissue calcium from necropsy material in pooled pancreatic and surrounding tissue of 6 patients dying of acute pancreatic necrosis were recorded. The amounts of calcium obtained varied from 200 milligrams to 1732 milligrams. The variable amounts of fat necrosis present in these necropsies are probably dependent upon the survival period after onset of the disease and the mechanism of death in different instances. The smallest amount, 200 milligrams, was in an instance in which the patient lived only 1 day whereas with the largest amount, 1732 milligrams, the patient had survived for 27 days. The high calcium figure (the 1732 mgm.) in this latter patient represents more than twice the amount of serum calcium in the normal average adult. That the lipase activity is greatest in the pancreas is shown by the results in these same 2 patients. In the former, dying in one day, the pancreas contained 132 milligrams of calcium per 100 grams of tissue while the surrounding tissue contained only 18 milligrams per 100 grams of tissue. In the patient surviving 27 days, these amounts were 178 milligrams and 152 milligrams, respectively.

Serum calcium. In a group of 50 patients with pancreatic necrosis total serum calcium measurements were made. The diagnosis was established by laparotomy in 10 of these, by autopsy in 3 not operated upon and in the remainder the clinical diagnosis was verified by repeatedly finding elevated levels of diastase in the blood or urine or both. Necessarily there were a small number in whom only one observation could be made while in many instances 7 to 10 observations were made on succeeding days. In all 151 serum calcium measurements were made. The data recorded have been pooled and an average of the readings for each day of the disease recorded graphically. This develops a curve representing a depression of blood calcium during the period of calcium soap formation with subsequent slow return to normal levels as the pancreatic lesion heals. Clinical improvement with return of the diastase levels to normal usually precedes by several days the tendency of the blood calcium to rise. Further, the calcium rise is slow and usually is not completed before the end of the second week. A parallel thereby exists with the known behavior of the blood lipase (Comfort). Low serum calcium beyond the second week usually means some complication or progression of the disease. Also in some patients the serum calcium returns to normal within the first week.

Consistent lowering of the blood calcium was manifested throughout the entire group of patients, there being only 4 patients in whom calcium did not fall below 9.9 milligrams per 100 cubic centimeters. In all patients in whom the total serum calcium fell to a level between 7 and 8 milligrams the process clinically was of major intensity. In the only 3 instances in which the level fell below 7 milligrams death followed. Other features in one such (K) case include an antemortem serum phosphorous of 8.4 milligrams per 100 cubic centimeters of serum, serum albumin and serum globulin of 2.8 grams each for 100 cubic centimeters of serum. The serum calcium values between 8 and 9 milligrams occurred in patients in whom the attacks were of only moderate severity.

Diffusible serum calcium. The constant relationships between total serum calcium, ionized calcium, and total serum protein were established by the work of McLean and Hastings. In 1932 they established that at any given level of total serum calcium, the diffusible fraction increased as the total serum protein decreased, but that 65 per cent of diffusible calcium represented the upper limit of normal. In the course of our observations on total serum calcium we attempted unsuccess-

fully to find reports substantiating this relationship in the presence of acute depletion of diffusible serum calcium. To provide such observations we measured the diffusible calcium in a small group of patients. A total of 35 measurements were made on 10 patients. The diffusible calcium in this group varied from 46 per cent to 77 per cent. Serum proteins were normal in two of these patients. This fact would suggest that as the abrupt fall of the serum calcium level takes place, the percentage of the diffusible fraction rises to pathological proportions in an attempt to maintain a normal amount of physiologically active calcium.

ANALYSIS OF STUDY

Although the qualitative changes in fat necrosis were elucidated by R. Langerhans many years ago, the quantitative phases of the fixation of calcium in the tissues appear to be significant as indicated by the autopsy findings herein reported in which an amount of dislocated calcium was found in and around the pancreas equal in amount to more than twice that present in the normal circulating blood. The findings of low serum calcium levels in all severe cases of pancreatic necrosis would imply that the large loss into the tissues is not readily compensated for by mobilization of calcium from normal body stores. The increased percentage of diffusible serum calcium appears to be compensatory to this lowering of the total serum calcium. These calcium disturbances may be of some importance in the diagnosis, prognosis, and treatment of acute pancreatic necrosis.

We have seen no severe cases in which the serum calcium was not lowered, thereby adding a laboratory finding which tends to substantiate the elevations of blood and urinary diastase. However, we have studied a number of patients with perforated duodenal ulcer who had high blood amylase levels and in whom the serum calcium was lowered to a moderate degree. That these changes are physiologically consistent is suggested by the fat necrosis which may also be present in perforated duodenal ulcer. Those patients whose serum levels were between 7 and 8 milligrams per 100 cubic centimeters of serum invariably presented a very severe form of the disease. Such an index of tissue injury may furnish a basis for establishing the diagnosis of acute pancreatic necrosis as distinguished from the socalled acute pancreatic edema. Prognostic importance of the serum calcium level is indicated by the fact that death occurred in all patients in this group whose serum calcium level fell below 7 milligrams per 100 cubic centimeters.

The explanation of tetany as observed in 3 patients may not be evident. In 1 patient a serum calcium level of 4.2 milligrams per 100 cubic centimeters of serum was undoubtedly the cause, but in another the serum calcium was 8.7 milligrams per 100 cubic centimeters of serum and the carbon dioxide combining power of the blood was 58 volumes per cent. This suggests that some other mechanism might have been responsible for the tetany. The possibility that serum magnesium might also be lowered by passage of magnesium into the areas of fat necrosis to form magnesium soaps is one that is now being investigated. Tetany due to magnesium deficiency is one that has never been reported in man but is easily produced in rats by a magnesium deficient diet (Kruse and associates). Low magnesium tetany has also been noted in cattle by Sjollema and in calves by Duncan and associates.

SUMMARY AND CONCLUSIONS

1. In 6 fatal cases of acute pancreatic necrosis it was found that from 100 to 1732 milligrams of total calcium were present in the areas of fat necrosis.

2. Serum calcium values below 9 milligrams per 100 cubic centimeters of blood were present in 36 of 50 clinical cases of pancreatic necrosis some time between the 2d and 15th day of the disease.

3. The average serum calcium value in the entire series was lowest on the 6th day of the disease (8.4 mgm.).

4. Serum calcium values returned slowly to normal in severe cases, lagging behind the clinical course of the disease.

5. Serum calcium values below 7 milligrams per 100 cubic centimeters of serum indicate a fatal prognosis.

6. The amount of diffusible serum calcium tends to remain stable in the presence of a decrease in total serum calcium.

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EXPERIMENTAL STUDIES IN PERIPHERAL NERVE SURGERY

I. The Effect of Sulfonamide Drugs upon Experimental Gunshot Wounds Involving Peripheral Nerves

LOYAL DAVIS, M.D., F.A.C.S., GEORGE PERRET, M.D., and WALTER CARROLL, M.D.,
Chicago, Illinois

THIS is the first of a series of articles dealing with experimental studies in the surgery of peripheral nerves. Succeeding papers will record the effect of the sulfonamide drugs upon nerve regeneration; the effect of sepsis upon regeneration and recovery of function; the relative recovery of function after end-to-end sutures and grafts, and the effect of resection of the primary distal suture line of grafts in the repair of peripheral nerve injuries. Four hundred and ten animals with experimental nerve injuries have been studied, representing a total of more than 800 operations. The majority of the animals used were cats, and the nerve involved was the sciatic. Procedures were standardized in so far as the same surgeons have performed all the operations and have followed the same method and technique. Standardized methods of clinical investigations performed by the same examiners have been used and give a unity to the entire problem.

This paper deals with the effects produced by the local application of the sulfonamide drugs upon gunshot wounds involving peripheral nerves.

OPERATIVE PROCEDURES AND TREATMENT

The aim in this study was to produce a wound with tissue destruction and severance of the sciatic nerve, the severity of which could be compared to the usual wounds of modern warfare. The wounds were produced at short range by .22 caliber, long rifle lead-tipped bullets whose tips were countersunk, or coned out, and which had a muzzle velocity of approximately 1070 feet per second. The wounds were uniformly characterized by a small round entrance on the lateral aspect of the thigh and a much larger, irregular and ragged area of exit on the medial aspect. The left leg of the anesthetized cat was suspended with full extension of the knee and the thigh slightly compressed in its medial-lateral axis by two wooden surfaces, thus immobilizing the soft tissues and reproducing the effect of an active muscle holding the nerve taut. An adequate opening in the lateral compressing board presented an unobstructed path for the bullet. This method resulted in a fairly constant and uniform severance of the left sciatic nerve and infrequently a fracture of the femur. Without compression of the thigh the nerve was usually only contused and pushed aside by the bullet. Prior to the injury the animal's thigh was shaved in order to prevent a too virulent and too massive wound infection. After the bullet wound was inflicted, a simple clean gauze dressing was applied and allowed to remain in place until the wound was débrided.

Débridement of the wound and simultaneous repair of the nerve were performed immediately and at various intervals until 48 hours after the injury. Of the 217 gunshot wounds studied, 74 were débrided immediately after injury, 27 after 6 hours, 15 after 12 hours, 26 after 18 hours, 53 after 24 hours, and 12 between 24 and 48 hours. Nerve repair and closure of the wound were performed in every animal despite the length of time which had elapsed between the injury and débridement. All surgical procedures were done with strict

From the Division of Surgery, Northwestern University Medical School.

The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Northwestern University.

aseptic precautions. Wound repair was preceded by cleansing the skin thoroughly with soap and water, followed by iodine, alcohol, and draping. The exit wound on the medial aspect of the thigh was first repaired. The débridement was complete in so far as all questionably devitalized tissue was completely excised. The skin edges were trimmed, the edematous subcutaneous tissue and the traumatized dusky red, or purple, discolored muscle were removed. All foreign bodies were removed. The wound was irrigated with saline solution and closed in layers with interrupted silk sutures and skin clips. The same procedure was used in closing the wounds of entrance, except that the exposure of the injured nerve required an incision sufficiently long to reflect the lateral musculature of the thigh.

Repair of the nerve was carried out after complete débridement and irrigation of the wound had been accomplished. The bullet produced an irregular and ragged severance of the nerve, and the nerve fascicles protruded from the epineurium and perineurium of the torn ends. The epineurium had usually retracted for a distance of 3 to 8 millimeters. Small blood clots were found around the epineurium and perineurium, and the epineurium appeared swollen, glossy, and seemed to contain clear fluid. Ecchymosis, discoloration, and edema affected both torn segments for a distance of 10 to 15 millimeters and the nerve showed a parallel striation which was perpendicular to its course and resembled muscle striae. Although the course of the bullet had been straight when piercing the thigh, the shot canal was found not to be continuous because the muscles had changed their position and state of contracture. Thus the relation of nerve to muscles was changed which explained that frequently the contused or torn nerve was no longer in the area of muscle destruction. Nerve repair consisted of a local neurolysis, trimming of the ragged nerve ends, resection of the severely contused nerve tissue and end-to-end suture, or implantation of a fresh homogenous graft depending on the amount of nerve destruction. The suture material used was fine black silk.

The gross appearance of the wounds surgically treated after 6 hours was indistinguishable from that immediately after injury, except for an occasional edema. Wounds which remained untreated more than 12 hours after injury presented characteristic signs of infection: the traumatized tissues became necrotic, grossly edematous, and developed an offensive odor. In several cases the entire thigh and leg were tumefied and grossly edematous. The most common organisms found (bacterial cultures taken just prior to

Fig. 1. Immediate débridement of gunshot wounds of the sciatic nerve.

Fig. 2. Immediate débridement of gunshot wounds of the sciatic nerve.

Fig. 3. Débridement of gunshot wound 6 hours after injury.

Fig. 4. Débridement of gunshot wound 24 hours after injury.

Fig. 5. Sixty days after immediate débridement of gunshot injury and end-to-end suture.

Fig. 6. Sixty days after débridement and end-to-end suture 6 hours after injury.

Fig. 7. Sixty days after débridement and end-to-end suture 12 hours after injury.

Fig. 8. Sixty days after débridement and end-to-end suture 18 hours after injury.

Fig. 9. Sixty days after immediate débridement and end-to-end suture of gunshot injury in which sulfanilamide was used.

Fig. 10. Sixty days after débridement and end-to-end suture 6 hours following gunshot injury in which sulfanilamide was used.

Fig. 11. Sixty days after débridement and end-to-end suture 12 hours after gunshot injury in which sulfanilamide was used.

Fig. 12. Sixty days after débridement and end-to-end suture 24 hours after gunshot injury in which sulfanilamide was used.

Fig. 13. Sixty days after immediate débridement and end-to-end suture of gunshot injury in which sulfathiazole was used.

Fig. 14. Sixty days after débridement and end-to-end suture 6 hours following gunshot injury in which sulfathiazole was used.

Fig. 15. Sixty days after débridement and end-to-end suture 12 hours following gunshot injury in which sulfathiazole was used.

Fig. 16. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.

Fig. 17. Sixty days after immediate débridement and end-to-end suture following gunshot injury in which sulfadiazine was used.

Fig. 18. Sixty days after débridement and end-to-end suture 6 hours following gunshot injury in which sulfadiazine was used.

Fig. 19. Sixty days after débridement and end-to-end suture 12 hours following gunshot injury in which sulfadiazine was used.

Fig. 20. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfadiazine was used.

Fig. 1

Fig. 2

Fig. 3

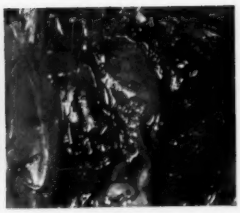
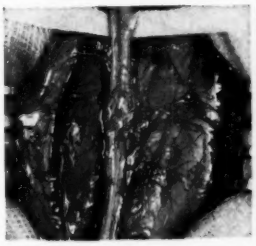


Fig. 4



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Experimental Studies in Peripheral Nerve Surgery.—
Loyal Davis, Frederick Hiller, George Perret, Walter Carroll

UNIV. OF MICH.

débridement) were Bacillus coli, nonhemolytic streptococci, Staphylococci albi, Bacillus proteus, Bacillus subtilis, and an occasional diplococcus.

In a series of animals various sulfonamide drugs were introduced locally into the wound at the time of débridement. The drugs used were powdered and crystalline sulfanilamide, powdered sulfathiazole, and sulfadiazine. The drugs were distributed evenly in the entire wound before closure. One-tenth gram (0.1 gm.) of drug was used per pound of animal weight, giving an average of 0.7 gram in each wound. The implanted powdered drugs developed a paste-like consistency, especially around the nerve, and were absorbed so slowly that 3 to 7 days were required before they had disappeared from the wound surfaces. Sulfanilamide was used in 37 animals, sulfathiazole in 35 animals, and sulfadiazine in 24 animals, while the wounds of 48 animals were not treated with any chemicals.

In 51 instances in which débridement was performed 24 hours or more after injury, a sulfathiazole jelly was introduced into the bullet tract at the time the wound was received. This jelly is water soluble and contains sulfathiazole in a concentration of 5, 15, or 25 per cent. Three to 5 cubic centimeters of jelly was introduced into the depths of the wound from a metal tube through a fitted flexible metal conduit. These wounds were débrided in the same way as in the other animals and in 40, sulfonamides were powdered into the wounds before closure. The sulfathiazole level in the blood was determined at the time of débridement. The average level was 1.69 milligrams per cent after 24 hours and 0.33 milligrams per cent after 48 hours.

TABLE I.—THE RELATION BETWEEN THE INCIDENCE OF INFECTION AND LOCAL CHEMOTHERAPY IN GUNSHOT INJURIES

Time of débridement after injury	Local chemotherapy	Total number of animals	Percentage of infection in wounds	
			Untreated	Treated
Immediate	None	34	38.2	
Immediate	Sulfonamides, and sulfathiazole jelly	40		5.0
6 hours	None	7	42.9	
6 hours	Sulfonamides	20		10.0
12 hours	None	3	33.3	
12 hours	Sulfonamides	12		25.0
18 hours	None	8	62.5	
18 hours	Sulfonamides	18		27.7
24 hours	None	6	83.3	
24 hours	Sulfonamides	18		55.5
24 hours	Sulfathiazole jelly alone	8		25.0
24 hours	Sulfathiazole jelly and sulfonamides	21		14.3
36 hours	Sulfathiazole jelly alone	1		100.0
36 hours	Sulfathiazole jelly and sulfonamides	3		33.3
48 hours	Sulfathiazole jelly alone	2		50.0
48 hours	Sulfathiazole jelly and sulfonamides	16		31.2

RESULTS

In spite of a careful débridement performed immediately after inflicting the gunshot wound, the rate of infection and formation of extensive abscesses which burrowed along the course of the sciatic nerve and the fascial planes of the muscles was very high when the sulfonamides were not used in the wounds locally. The rate of massive infections increased the longer débridement was delayed. Thus in the series in which no sulfa drugs were implanted massive infections were encountered in 38.2 per cent of the 34 animals treated immediately after injury and in 42.9 per cent of the 7 animals operated upon 6 hours after injury. In the 11 animals débrided within 12 to 18 hours after injury, massive infections developed in 54.5 per cent of them, and this incidence grew to 83.3 per cent of the 6 animals treated after an interval of 24 hours. These infections usually became apparent 5 to 7 days after débridement, repair, and closure of the wounds, and most of them developed rapidly into generalized septicemia and death, even though drainage was instituted as soon as the infection was noticed.

The local application of the sulfonamide drugs in the wounds at the time of débridement did not completely prevent the formation of infection. In this group of animals the rate of infection was also directly proportional to the period of time which had elapsed before the wounds were treated. The incidence of in-

fection was 5.0 per cent of 40 animals when the wound was treated immediately with powdered sulfonamides or sulfathiazole jelly, 10 per cent of 20 wounds débrided after 6 hours: 26.6 per cent of 30 animals treated within 12 to 18 hours, and 55.5 per cent of 18 animals treated after 24 hours.

The immediate introduction of sulfathiazole jelly into the wound reduced the incidence of infection, especially in the wounds whose repair was delayed for 24 to 48 hours. When no further sulfonamides were used the rate of infection was 36.3 per cent of 11 animals, and this figure was reduced to 22.5 per cent in 40 cases when powdered sulfonamides were implanted in the wound at the time of débridement.

The toxicity of the drugs as manifested in this series lies somewhat in the realm of conjecture. Fourteen animals died within 2 to 4 days after surgery from uncertain causes. Nine of the deaths occurred prior to the use of the jelly, and 5 of these animals received no chemicals, while the other 4 were treated with sulfanilamide and sulfathiazole at the time of débridement. The remaining 5 animals were in the jelly series, 3 of which also received sulfanilamide, 1 sulfathiazole, and 1 sulfadiazine at the time of débridement. Careful autopsies revealed no clues related to the cause of death. The kidneys of 18 animals were studied histologically and failed to present the changes reported as due to the use of sulfonamides (1, 3). The considerable amount of large fat droplets in and around the convoluted tubules has been reported in normal cats (2), and there is no reason to believe that the drugs should produce any lipoid degeneration. The blood levels obtained after the introduction of the soluble sulfathiazole jelly in the wounds also speaks against the probability of a toxic effect. Furthermore, in the course of experimenting on such a large number of animals, an occasional debilitated cat was used and it is only logical that such an animal would succumb from the traumatization or experience a fatal postoperative course.

The extensive débridement of muscle and nerve considerably changed the original nerve bed, the surfaces and the relation of the surrounding tissues. These changes produced an extensive scar formation and dense adhesions were found around the repaired nerve and usually embedded the suture lines and both central and distal segments for a distance of 10 to 15 millimeters above and below the suture line, which was always moderately swollen. The adhesions were much more severe than those found in other series of animals in which aseptic nerve sections and sutures were performed. Because of the severity of the posttraumatic scar formation only little difference could be noted between the wounds which were treated with the drugs and those which were not. In a few instances, however, thicker and firmer adhesions have been noticed following the use of sulfanilamide powder. The use of the sulfathiazole jelly did not alter the amount of adhesions around the nerve and did not seem to hinder tissue repair in any noticeable way.

DISCUSSION

From the bacteriologic cultures and the high frequency of serious infections it is evident that the wounds resulting from gunshot injuries in our experimental animals showed a maximum of gross contamination and of tissue damage. It was not possible to reduce the seriousness of these infections with immediate thorough cleansing and careful wound excision and perform a satisfactory nerve suture and primary closure at the same time.

Our aim was to perform an immediate repair of the severed nerve in order to obtain earlier and, if possible, better functional results. From the experiences of the last war it appeared that the delay between nerve injury and nerve repair, which usually varied between 4 and 6 months, might be one of the reasons for the poor results obtained. From the 80,000 peripheral nerve injuries reported by Foerster, Spielmeyer and others, only 50 to 60 per cent showed some improvement following delayed nerve suture. Surgically, it is less difficult to suture a freshly severed nerve, and extensive trophic disturbances, severe muscle atrophies, and contractures are less likely to occur after early nerve repair. Thus, the effector mechanisms can be more easily kept in condition to resume function when regeneration has taken place. The incidence of infec-

tion, when wound cleansing, débridement, nerve repair, and closure were performed within 12 hours after injury, was lower in the series of animals in which the sulfonamide drugs were applied locally to the wound.

Another purpose of these experiments was to find out how long débridement followed by immediate nerve repair and wound closure could be delayed without a prohibitive incidence of infection. There was a high incidence of infection when débridement was delayed more than 12 hours; it was very high when the delay was 24 hours or more. The introduction of sulfonamides into the wound reduced the incidence of infection only slightly, and it seemed that immediate nerve repair *after* 12 hours was doomed to failure. During the delay the infection had already progressed to such an extent that débridement and local chemotherapy proved ineffective. MacLeod has shown that certain inhibitors to the sulfonamides occur in devitalized tissue and especially so the longer the wound remains open. Since all gunshot wounds are grossly contaminated, it was only logical to think that local chemotherapy applied earlier could overcome or at least reduce the developing infection. It is not possible to introduce the powdered or crystalline drug into the tortuous and complicated wound adequately and for that reason a sulfathiazole jelly was used which could reach most of the crevices and recesses of the wound. The introduction of this jelly into the wound immediately after the gunshot injury was inflicted reduced the incidence of infection in all of the experiments upon delayed débridement.

If the sulfathiazole jelly prevents bacterial invasion, its effect is only temporary and therefore cannot altogether prevent the formation of a later infection in a delayed wound. The early introduction of the jelly is only a preventive measure and there are no reasons to minimize the necessity of surgical asepsis. All wounds need to be adequately cleansed, débrided, and have additional local sulfonamide therapy before closure to obtain the best results. Thus the incidence of infection in wounds repaired 24 to 48 hours after injury was reduced from 83.3 per cent in 6 animals to 22.5 per cent in 40 animals, when sulfathiazole jelly was introduced into the wound immediately after its receipt, and sulfonamides were powdered into the wound at the time of débridement.

SUMMARY

1. The incidence of infection in gunshot wounds involving peripheral nerves surgically treated immediately after injury was reduced from 38.2 per cent to 5.0 per cent and from 42.9 per cent to 10 per cent when débrided 6 hours after injury when the sulfonamide drugs were applied locally to the wounds.

2. The incidence of infection in gunshot wounds involving peripheral nerves surgically treated 12 to 18 hours after injury was reduced from 54.5 per cent to 26.6 per cent; after 24 hours from 83.3 per cent to 55.5 per cent when the sulfonamide drugs were applied locally to the wounds.

3. The introduction of sulfathiazole jelly into the bullet tract at the time of injury, followed by surgical treatment 24 to 48 hours later and the local application of sulfonamide drugs to the wounds, was followed by a reduction in the incidence of infection from 83.3 per cent to 22.5 per cent.

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II. The Effect of Sulfonamide Drugs upon the Regeneration of Peripheral Nerves

LOYAL DAVIS, M.D., FREDERICK HILLER, M.D., GEORGE PERRET, M.D., and WALTER CARROLL, M.D., Chicago, Illinois

INJURIES of the peripheral nerves which result from war wounds are usually associated with extensive soft tissue destruction and fractures of the bones. In any event they are contaminated or grossly infected so that the liberal use of the sulfonamide drugs at the time of injury or débridement is indicated in an effort to control the course of the infection. It is of importance, therefore, to know what effect the sulfonamides might have upon the repair and regeneration of the peripheral nerve. If the use of the sulfonamide drugs will allow a peripheral nerve wound to be repaired after a shorter interval following injury without the danger of the development of a suppurating wound, and if they have no deleterious effect upon nerve regeneration, then the ultimate functional results of the repair of nerve injuries will be improved.

MATERIAL AND METHODS

In a group of 156 cats the left sciatic nerve was sectioned surgically; in one group under aseptic conditions and another group without sterile precautions. The nerve was sectioned and repaired immediately by end-to-end sutures in 34 cases; by implantation of an autogenous graft in 57, and by implantation of a homogenous graft in 65 cases. Seventeen of the animals operated upon under septic conditions developed an uncontrollable infection and were disregarded for further histological or clinical studies. In the remaining 139 animals, powdered sulfanilamide was used around the repaired nerve of 26, sulfathiazole in 28, and sulfadiazine in 23 animals; the remaining 62 animals were not treated with any of the drugs and were considered as control experiments. One-tenth gram of the powdered sulfonamide drugs[1] per pound of the animal's weight was sprinkled around the exposed sciatic nerves; the average dose was 0.7 gram.

The sciatic nerve was exposed by an incision made in the lateral aspect of the thigh, parallel to the femur, which separated the biceps femoris and vastus lateralis muscles. The nerve was sectioned with a thin razor blade and the cut ends were approximated by 5 or 6 sutures uniting the epineuriun. The sutures employed were single strands of black twisted Champion surgeon's silk No. 4. The sutures were not introduced until all epineural bleeding had stopped. The nerve bed was kept moist with normal saline solution. The autogenous and homogenous grafts measured from 2.0 to 2.8 centimeters in length.

The nerves repaired by end-to-end suture were examined at intervals of 14, 18, 30, 40, 45, 50, 60, and 75 days after the operation. The autogenous and homogenous grafts were allowed to regenerate for 90, 120, and 150 days. Longitudinal and cross sections of the formalin fixed nerves were stained by the Bodian-fuchsin, Weil, van Gieson, and Sudan III methods.

In 2 animals for each drug, the exposed sciatic nerves were not sectioned but sulfanilamide, sulfathiazole, and sulfadiazine were implanted about the nerve trunks and the wounds were observed at frequent intervals for a period of 48 and 72 hours. The nerve was then removed for study. After 2 hours the powdered drugs became wet; after 5 hours the material gathered in large clumps around the nerve and the presence of clear fluid could be seen in the wounds. This serous exudate increased steadily for 24 hours and collected in pools in various parts of the wounds. After

From the Division of Surgery, Northwestern University Medical School.

The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Northwestern University.

[1] Fine crystalline sulfanilamide, sulfathiazole, and sulfadiazine powders were used in all the experiments.

24 hours some of the sulfanilamide, sulfathiazole, and sulfadiazine powder had been absorbed; however, most of it clung in small clumps to the nerve itself. After 48 hours a large amount of the sulfanilamide had been absorbed, while the sulfathiazole and sulfadiazine clumps were loosely adherent to the nerve and its surrounding tissues. These clumps had the appearance of curdled milk and the consistency of chewed gum. After 72 hours small clumps of sulfanilamide powder were still adherent to the nerve, while the other drugs were still present in larger amounts.

The wounds treated with the sulfonamide compounds were characterized by an increased amount of adhesions fixing the nerve to the surrounding tissues. The increase in the amount of adhesions between the epineurium and the surrounding muscles was a constant finding in both end-to-end sutures and in graft repairs, whether or not the operation had been performed with an aseptic or septic technique. These adhesions had a silvery, spider-web-like appearance, could be easily torn, and were moderately vascular. They were thicker and more extensive about the grafts, and in some instances fixed the graft to the surrounding tissues so that the nerve had to be dissected away. The distal suture line of the grafts was usually thicker and more often adherent to the surrounding tissues than the central suture, and this condition was more marked in homogenous grafts. However, thicker adhesions and more prominent central and distal suture lines were observed in the grafts treated with the sulfonamides. In general it appeared that the nerves treated with sulfanilamide powder showed more adhesions than those in which the other two compounds were used; however, this difference was small and could easily be overlooked.

Microscopic examination of nerves sutured end to end, under aseptic conditions, showed regenerated nerve fibers in the distal segment after 30 days (plus 2) in all cases; after 45 days (plus 3) in those nerves in which no drugs were used and in those in which sulfanilamide powder was introduced, and were less plentiful (plus 2) in those nerves in which sulfathiazole and sulfadiazine were used. After 60 days, the number of regenerated fibers was equal (plus 3) in all of the nerves with or without the sulfonamide drugs. The formation of thick, well developed axis cylinders (in contrast to numerous fine regenerated nerve fibers) growing in the proliferative endoneurium (Büngner bands) of the distal segment was found insignificant after 30 days in all cases, and well under way after 45 and 60 days in all cases. The formation of myelin sheaths was practically absent after 30 days, just beginning after 45 days, and well established after 60 days in all cases. Myelin decomposition products were found after 30 and 45 days in all cases (plus 3) and were less (plus 2) in all 60 day animals.

A study of the suture line of the end-to-end anastomoses showed a slight (plus 1) epineural proliferation after 30 days in the group of cases in which no drugs were used and in those in which sulfanilamide had been implanted. In those experiments in which sulfathiazole and sulfadiazine were used the epineural proliferation was more marked, plus 2 and plus 3, respectively. After 45 days the epineural proliferation was slight (plus 1) in the untreated group and those in which sulfanilamide and sulfathiazole were used the proliferation was increased (plus 2) and was still more marked (plus 3) in those cases in which sulfadiazine was introduced. After 60 days in the untreated and sulfathiazole groups the proliferation was moderate (plus 2) and more marked (plus 3) in the sulfanilamide and sulfadiazine experiments. The number of deviating nerve fibers fanning out from the central segment into the proliferating epineurium corresponded to the quantity of epineural proliferation in each instance.

It may be said that the use of the sulfonamide drugs increases the mesodermal proliferation at the suture line and, at the same time, leads to a more intense neurotization of the scar tissue in the suture line. To determine more clearly the effect of these drugs on the mesodermal nerve sheaths, particularly the epineurium, a study was made of the surface of the central and distal segment at a distance of 1 to 2 centimeters away from the suture line.

After 30 days the group I specimens (without drugs) showed a moderate cellular and

fibrous epineural proliferation with increased vascularization and predominently lymphocytic foci, but also a leucocytic infiltration which increased toward the suture line and over the distal segment. In the group II specimens (sulfanilamide) the same type of reaction, but somewhat more marked, was seen. In the group III specimens (sulfathiazole) there was very little cellular and fibrous proliferation over the central segment, but the lymphocytic and histiocytic proliferation was more pronounced and there was a very marked vascularization of the distal segment. In group IV (sulfadiazine) a very marked cellular and fibrous proliferation with excessive vascularization was present over the central segment. These findings were still more marked over the distal segment combined with lymphocytic infiltrations, with hemorrhages around the residual particles of sulfadiazine. Adhesions to the surrounding muscles were present in the group IV specimens (sulfadiazine), showing the granulation and mesodermal scar tissue infiltrating into the adherent muscle.

The impression obtained from these observations is that the suture itself produces sufficient trauma to the nerve to cause a moderate epineural and perineural reaction which simulates the appearance of an inflammatory lesion. The use of sulfanilamide and sulfathiazole produced a more pronounced mesodermal reaction and sulfadiazine was followed by definitely stronger cellular and fibrous mesodermal reaction.

After 45 days group I specimens (no drugs) showed a slight fibrous proliferation with increased vascularization and scattered moderate lymphocytic infiltrations over the central, but much more over the distal, segment. In the group III specimens (sulfathiazole) a pronounced epineural fibrous proliferation with marked vascularization and many lymphocytic foci was present. The same findings, but still more pronounced, were present over the distal segment, and the cellular proliferation was intense, containing numerous histiocytes. In the group IV specimens (sulfadiazine) there was a strong fibrous epineural proliferation with moderate lymphocytic infiltration and hypervascularization which increased toward the suture line and was even more marked over the distal segment where the proliferative epineurium surrounded amorphous material with cell detritus and where there was a large amount of lymphocytic infiltration.

After 60 days the group I specimens (no drugs) showed a moderate spongy fibrous epineural proliferation with very few lymphocytic foci but marked vascularization over the central as well as the distal segment. In the group II specimens (sulfanilamide) there was a moderate, dense fibrous proliferation of the perineurium with increased vascularization and quite a few lymphocytic foci over both segments. In the group III specimens (sulfathiazole), a spongy, fibrous proliferation of the epineurium with slight vascularization, was present, but there were few lymphocytic infiltrations in either the central or distal segments. In the group IV specimens (sulfadiazine), a fair amount of spongy, fibrous proliferation with marked hyperemia, and no lymphocytic infiltrations, was present over the central segment, but there was an intense epineural proliferation over the distal segment.

Fig. 21. Sixty days after end-to-end suture of surgically divided peripheral nerve.

Fig. 22. Sixty days after end-to-end suture of surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 23. Sixty days after end-to-end suture of surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 24. Sixty days after end-to-end suture of surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 25. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve.

Fig. 26. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 27. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 28. Seventy-five days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 29. Seventy-five days after introduction of a homogenous graft in peripheral nerve which had been surgically divided.

Fig. 30. Sixty days following the introduction of a homogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 31. Seventy-five days following introduction of a homogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 32. One hundred twenty days following the introduction of a homogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 21

Fig. 22

Fig. 23

Fig. 24

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Fig. 31

Fig. 32

Experimental Studies in Peripheral Nerve Surgery.—
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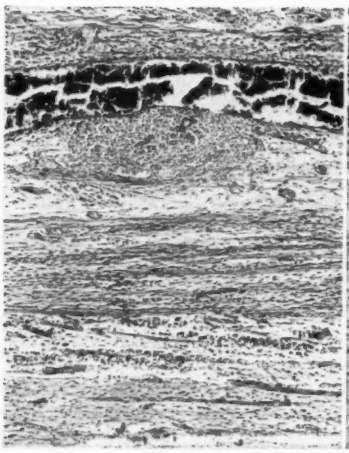

Fig. 33

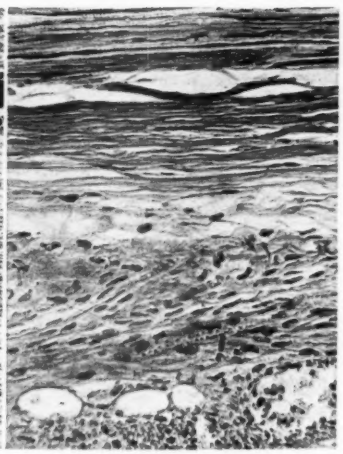

Fig. 34

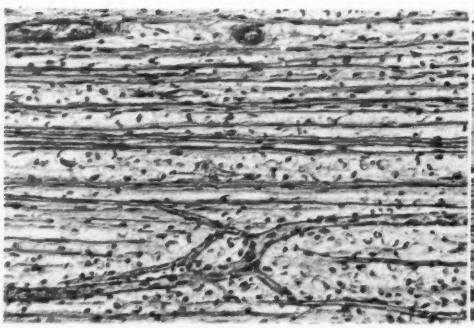

Fig. 35

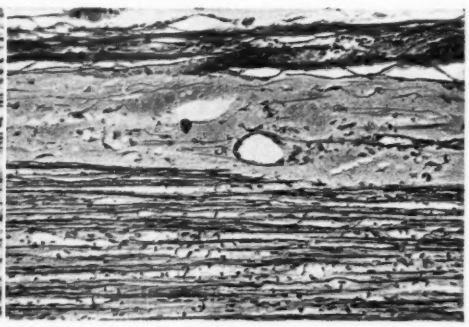

Fig. 36

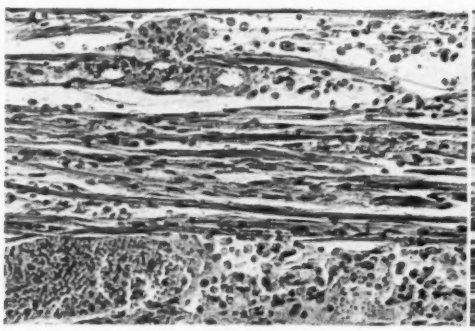

Fig. 37

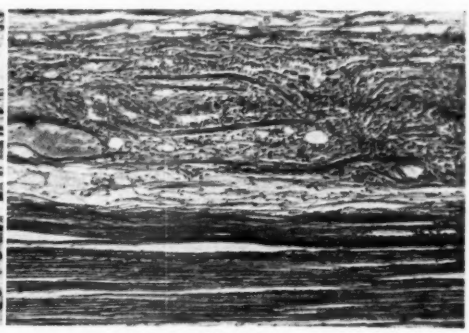

Fig. 38

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The epineural proliferation apparently loses its chronic inflammatory appearance after 60 days in the central and distal segments and does not resemble that about the suture line. The comparison of the intensity of the epineural reaction of the 30, 45, and 60 day experiments showed a gradual decrease of epineural proliferation in the untreated, sulfanilamide and sulfathiazole specimens, whereas the sulfadiazine group revealed a persisting marked proliferative reaction throughout. The lymphocytic perineuritis, which apparently was not a true inflammatory reaction, was found in all experiments up to 45 days but had disappeared in the sulfadiazine group after 60 days. The animals treated with sulfanilamide showed moderate evidence of a true neuritis after 30 and 45 days. In general, it may be said that sulfadiazine seems to provoke a stronger mesodermal reaction, perhaps because of retarded absorption, but it does not create the picture of a lasting chronic perineuritic inflammation.

A study of the specimens of end-to-end sutures performed under septic conditions showed that the regeneration of nerve fibers, as well as axis cylinder formation, myelinization, and myelin decomposition organization presented no appreciable differences from these findings in the experiments performed aseptically. In general it may be said that the sulfonamide drugs protect the nerves from a true neuritis, or overcome this neuritis, which was found to persist in 30, 45, and 60 day groups of the nontreated animals.

In the specimens of the aseptic as well as the septic experiments, no evidence was found that the regeneration of nerve fibers, axis cylinder formation, the myelinization or the absorption of myelin decomposition products was changed by the use of the sulfonamide drugs. It should be noted on the other hand that a strong mesodermal reaction, which occurs around the site of the nerve suture leads to a deviation of regenerating nerve fibers into this proliferating tissue to the degree to which granulation and scar tissue is formed around the sutures. When mesodermal elements invade the surrounding muscles, nerve fibers will often be seen growing with the mesodermal fibers into the perimysium of the muscle. Wherever the same kind of mesodermal proliferative reaction takes place on the surface of the central or distal segment, as a continuation of the mesodermal reaction at the suture sites, again regenerating nerve fibers can be seen coursing within the epineurium of the central or distal segment. These deviating epineural nerve fibers over the central segment must be regarded as retrograde fibers, since they originate from the fanning out end of the central segment. This observation, noted in a great number of specimens, appears to be evidence against the gen-

Fig. 33. Aseptic end-to-end nerve suture, sulfathiazole—45 days. Photomicrograph of distal segment showing marked hyperemia, lymphocytic infiltration, edema, and a general cellular and fibrous proliferation of the perineurium. There are a few regenerating nerve fibers which can be identified in the epineurium. (Bodian-fuchsin stain × 50).

Fig. 34. Aseptic end-to-end nerve suture, sulfathiazole—30 days. The distal segment is in full regeneration; the endoneural tubes are filled with myelin decomposition products, and a considerable number of gitter cells have accumulated around capillaries. The endoneurium reveals a two plus cellular proliferation and a rather uniform regeneration of nerve fibers following the endoneurium. (Bodian-fuchsin stain × 145).

Fig. 35. Aseptic end-to-end nerve suture, sulfathiazole—45 days. Photomicrograph of the central segment showing undamaged axis cylinders and myelin sheaths without cellular proliferation; a somewhat thickened perineurium, and a proliferative epineurium with a strong vascularization. Schwann cells with regenerating nerve fibers passing between the mesodermal fibers are seen. This is a typical example of a retrograde neurotization in the central segment. (Bodian-fuchsin stain × 225).

Fig. 36. Aseptic end-to-end nerve suture, sulfadiazine—45 days. This specimen shows a subperineural edema seen commonly over the distal segment. The edema seems to be entirely inside the perineurium but does not penetrate to any measurable amount between the regenerating nerve fibers. It must be of some duration by virtue of the fact that quite a number of pyknotic nuclei and degenerating cells are seen within the edema. It is particularly interesting to see that the nerve fiber regeneration in the endoneurium is just as good close to the edema as far away. (Bodian-fuchsin stain × 85).

Fig. 37. Aseptic end-to-end nerve suture, sulfadiazine—45 days. The epineurium of the distal segment is in a state of lively cellular and fibrous proliferation. Between the proliferating mesodermal fibers chains of Schwann cells can be seen carrying regenerating nerve fibers. There is a marked hyperemia and some cellular exudate. (Bodian-fuchsin stain × 225).

Fig. 38. Aseptic end-to-end nerve suture, sulfadiazine—30 days. A low power photomicrograph of the central segment showing a thickened perineurium, a highly proliferative vascular epineurium, and lymphocytic infiltrations. There is a large number of regenerating nerve fibers which take their course from the suture line backward into the epineurium of the central segment. (Bodian-fuchsin stain × 65).

erally accepted theory that the degenerating distal segment of a cut nerve exerts a kind of chemotropic influence on regenerating nerve fibers growing out of the end of the central segment. The truth of the matter is that nerve fiber regeneration will follow the path of proliferating histiocytes, be it in the granulation tissue that fills the gap between the central and distal segment, or in the proliferating endoneural sheaths of the degenerating distal segment, or whenever a histiocytic proliferation takes place around the sutures, which extend into the epineurium over the central or the distal segments. Further studies are being made to determine whether and to what extent a proliferation of Schwann's cells into the proliferating histiocytes is involved in this process.

The deviation and abnormal distribution of regenerating nerve fibers can be seen regardless of whether a strong mesodermal suture reaction or an epineural reaction is traumatic, infectious, or is caused by the irritation of the sulfonamide drugs. Extending as far as 1.5 centimeters in the epineurium of the central segment and almost 2 centimeters in the epineurium of the distal segment, it is definitely more pronounced in the specimens in which the sulfonamide drugs were used. This fiber deviation is well developed after 30 days and later these fibers become myelinated.

In a series of experiments autogenous and homogenous grafts were used, and the sulfonamide drugs were introduced into the wounds. To evaluate the effect of these drugs upon nerve regeneration through grafts, comparative studies have been made of the experimental material in control animals and those in which the drugs were used. All of the experiments hereafter described were performed under aseptic conditions and the analogous experiments conducted under septic conditions are not considered because additional factors, the most important of which is infection, would complicate an interpretation of the effect of the drugs.

Central and distal sutures were made between the graft and the ends of the divided nerve. After 45, 60, and 75 days the area of the distal suture line was usually resected and resutured, in accordance with an experimental program to be reported upon later. The resected area, which represented the distal end of the graft, the line of suture, and the central end of the distal nerve segment, was studied microscopically and the entire specimen of nerve trunk and graft was removed for study after subsequent intervals of 45, 60, and 75 days.

Sixty days after the implantation of an *autogenous* graft, the distal segment of nerve showed nerve fiber regeneration which varied between 1 plus and 2 plus. There was a beginning axis cylinder and myelin sheath formation which varied in degree in the different specimens, but there was no difference between the specimens obtained in the nontreated and treated experiments. Studies of the entire specimen after a subsequent 60 day interval following resection and resuture at the distal suture line confirmed these findings.

A comparative study of the histological appearance of the area of the primary and secondary distal suture lines and the central suture line showed that the differences of the individual experiments within each group were more pronounced than the differences between the nontreated, sulfanilamide, sulfathiazole, and sulfadiazine groups. The proliferation of the perineurium and epineurium in the graft varied between 2 and 3 plus with a slightly stronger reaction in the sulfonamide drug experiments. Adhesions to surrounding muscles were present in untreated and treated animals to an equal degree.

It appears that the irritation caused by the implantation of an autogenous graft varies between experiments and is not conspicuously affected by the use of the sulfonamide drugs. The appearance of regenerating nerve fibers in the perineurium and epineurium of the graft, which we believe depends upon the survival of endoneural sheaths in the grafts, is not affected by the sulfonamide drugs.

Therefore, it may be said that experiments with autogenous nerve grafts under aseptic conditions show that the sulfonamide drugs do not interfere with the neurotization of the graft or the distal segment. Mesodermal proliferation at the area of the suture lines, and in the grafts, varies for one reason or another between experiments but there is no evidence

that the use of the sulfonamide drugs is a determining factor.

The area of the central suture line in the *homogenous* graft specimens showed an equal mesodermal reaction in the nontreated and treated animals with the same individual variation between experiments in each group. The same was true of the areas about the primary and secondary distal suture lines. Nerve fiber regeneration, axis cylinder and myelin sheath formation were equally prominent in the distal nerve segment of nontreated and treated animals. There was slightly more perineural and epineural proliferation in the homogenous grafts of the sulfonamide treated animals, but the perineural neurotization was equally advanced.

One striking difference between the nontreated and treated animals in the homogenous graft series was that an heteromorphous neurotization of the graft was found in all of the sulfonamide treated animals, whereas the grafts in the untreated animals showed in all instances at least some degree of isomorphous neurotization. This may be explained by a more intense and irregular endoneural mesodermal reaction initiated by the sulfonamide drugs in homogenous grafts in which are found large areas of necrosis which destroy the original endoneural structure and lead to a heteromorphous mesodermal infiltration from without.

It may be said, therefore, that the neurotization of the distal segment in homogenous grafts is not altered by the introduction of the sulfonamide drugs. More so than in the autogenous grafts, it appears that the mesodermal reaction of the perineurium and epineurium of the homogenous graft is more marked under the influence of the sulfonamide drugs.

SUMMARY

The use of the sulfonamide compounds in experimental wounds produced an increased amount of adhesions which fixed the nerve to the surrounding tissue. These adhesions were thicker and more extensive about the grafts, particularly the homogenous grafts. The use of the sulfonamide drugs was accompanied by an increased mesodermal proliferation at the suture line and at the same time led to a more intense neurotization of the scar tissue in the suture line. This was in addition to the moderate epineural and perineural reaction produced by the trauma of the suture. In general, it may be said that sulfadiazine provoked the most marked mesodermal reaction, perhaps because of retarded absorption, although the findings were in no instance those of a lasting chronic perineuritic inflammation.

No conclusive evidence was found that the regeneration of nerve fibers, axis cylinder formation, myelinization, or the absorption of myelin decomposition products was changed by the use of the sulfonamide drugs. The deviation and abnormal distribution of regenerating nerve fibers were observed regardless of whether a strong mesodermal suture reaction or an epineural reaction was traumatic, infectious, or was caused by the irritation of the sulfonamide drugs.

The sulfonamide drugs did not interfere with the neurotization of an autogenous or homogenous graft, or the distal segment. However, in the homogenous graft series a heteromorphous neurotization of the graft was found in all of the sulfonamide treated animals whereas similar grafts in untreated animals showed in all instances some degree of isomorphous neurotization.

PERILUNAR DISLOCATION OF THE CARPAL BONES AND DISLOCATION OF THE LUNATE BONE

W. RUSSELL MACAUSLAND, M.D., Boston, Massachusetts

THE numerous contributions to medical literature, during the past 15 years, on dislocations that concern the lunate bone are proof of continued interest in this field. Recurrent discussion has been provoked, for the most part, by two factors. In the first place, the surgeon feels concern that these injuries are seen too often in the late stage when conservative treatment is useless, and when even skilful operative interference may be followed by serious functional changes in the wrist and hand. Either the lesion continues to be overlooked, or the findings are misinterpreted in the early stage. Second, because of the diversity of opinion as to whether operative reduction or excision of the lunate bone is the better treatment when conservative measures fail or when the dislocation is of long standing, surgeons have been stimulated to record their experiences and to try to arrive at some reliable conclusions. Still another impetus to discussion of these luxations has been the need of clarification of the conception of dislocations involving the lunate bone. This aspect of the lesion has been considered by foreign writers far more than by English contributors.

The purpose of the writer in adding to the literature on this subject is three-fold: (1) to emphasize again the importance of early diagnosis and treatment; (2) to describe in simple form the dislocations that concern the lunate bone; and (3) to present the observations and results in a series of 24 cases.

TYPES OF DISLOCATION

Research of this subject reveals that dislocations involving the lunate bone are designated by as many as 10 different terms. Thus the lesions are referred to as: dislocations of the lunate bone, dislocations of the carpus, subtotal retrolunar subluxation of the carpus, backward displacement of the os magnum, or perilunar luxations of the carpus. Not only is such extensive terminology confusing, but a clear picture of the types of dislocations is seldom presented. Most writers have, in fact, grouped all dislocations under the term *dislocations of the semilunar or lunate bone*, whereas this bone may lie in practically normal position, with the carpal bones dislocated around it. Other writers prefer the use of the term "perilunar luxation of the carpus," and include under it actual displacements of the lunate bone.

It would seem necessary to recognize 2 typical dislocations involving the lunate bone, a simple classification that is based upon the special joint relations existing at the time of examination. The first type is the perilunar dislocation of the carpus in which the distal row of carpal bones is displaced around the lunate bone, while the latter retains its normal or practically normal relationship with the radius (Fig. 1). The dislocation is usually backward and upward, and may be complicated by a fracture of the navicular bone or of a styloid process, although a perilunar dislocation toward the volar aspect is not unknown (Fig. 2). The second type is a dislocation of the lunate bone itself, usually volarward (Fig. 3).

Observers who have been particularly interested in the mechanism of these injuries claim that all dislocations involving the lunate bone are of the perilunar type at the start, and that the dislocation of the lunate itself is a secondary stage of a luxation of the carpal bones.

This may be true, but the fact that the lunate actually dislocates, losing its relation with the radius, and that under such circumstances treatment different from that of the perilunar luxation is called for, makes it necessary to consider the secondary dislocation as a separate entity regardless of the theories of mechanism.

From the MacAusland Orthopedic Clinic.

Fig. 1. A. P. A fresh dorsal perilunar dislocation of the carpal bones complicated by fractures of the navicular bone and the ulnar styloid process.

Fig. 2. H. S. a, left, A fresh volar perilunar dislocation of the carpal bones. b, Reduction obtained by the manipulative method.

The lunate bone, when dislocated volarward, may be found to have pivoted on the intact volar radiocarpal ligament so that it lies rotated from 90 to 270 degrees (Fig. 4). Usually the bone is found rotated about 90 degrees. In severe cases in which the volar radiocarpal ligament also is ruptured, the lunate may lie entirely free in the soft tissue in front of the forearm bones.

Both types of dislocation, but more often the perilunar, may be associated with other carpal injuries, in particular with a fracture of the navicular bone and less often with a fracture of the radial or ulnar styloid process. The navicular is fractured transversely through the midline, and the proximal fragment remains in contact with the lunate bone, displacing with it or retaining its relation to the radius according to the type of lesion, whereas the distal fragment is displaced with the carpal bones. In 11 of the 24 cases being reported (1 bilateral case), there was an associated fracture of the navicular either alone or in combination with fractures of the styloid processes, and in 5 cases the styloid processes were fractured.

MECHANISM

The generally accepted theory of the mechanism of both perilunar luxations and dislocations of the lunate is as follows: A person in

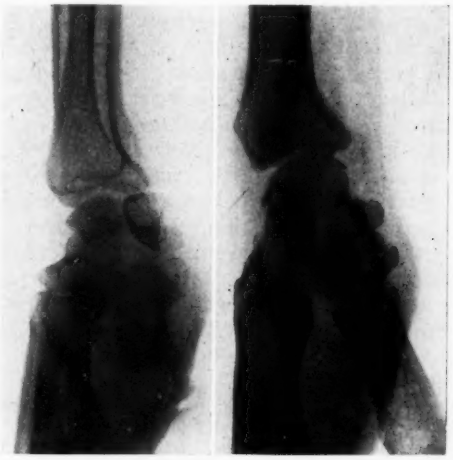


Fig. 3. C. H. a, left, A fresh volar dislocation of the lunate bone. Note the rotation of the lunate and loss of normal relationship with the radius. b, Roentgenogram following manipulative reduction.

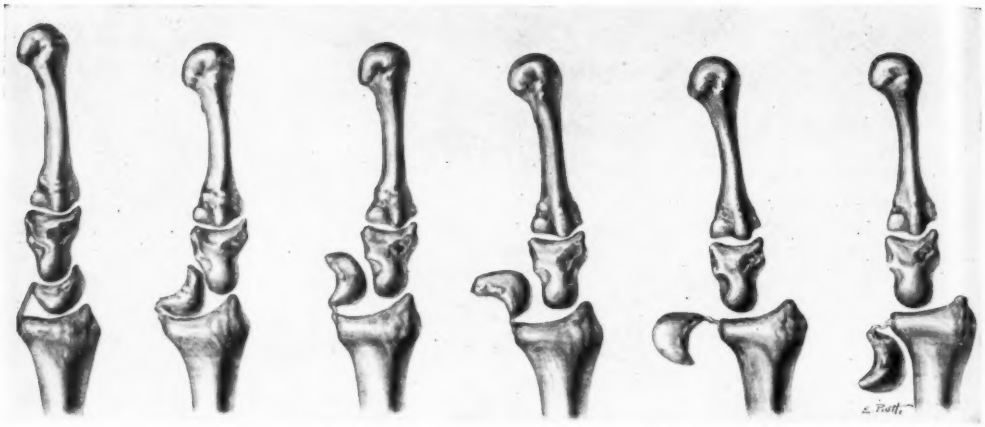


Fig. 4. The lunate bone in normal position and in varying degrees of rotation.

falling may land on the outstretched hand, forcibly hyperextending the wrist. The capitate bone accompanied by the distal row of carpal bones rides upward and backward. The volar ligaments between the lunate and the capitate are torn, but the volar and dorsal ligaments between the radius and the lunate remain sufficiently intact so that the lunate maintains practically normal contact with the radial surface. The dorsal surface of the lunate may displace slightly forward, but no true rotation of the bone takes place owing to the intact dorsal ligament and capsule. Thus the perilunar type of dislocation is produced.

When the capitate in its backward course is forced against the radial margin, the lunate bone under the pressure may be squeezed forward out of its socket. This may happen at the time of the original injury or secondary to a perilunar dislocation. In such cases the dorsal radiocarpal ligament attached to the surface of the lunate is torn. The lunate then proceeds to rotate forward and upward on the intact volar radiocarpal ligament. Eventually the head of the capitate may come to articulate with the radius (Fig. 4).

In the usual dorsal dislocation of the lunate bone, the mechanism is the reverse of that in volar dislocations. The injury is one of forcible hyperflexion of the hand in which the capitate and distal carpal bones displace volarward around the lunate bone. The volar radiocarpal ligament connecting the radius and the lunate gives way, and the lunate is squeezed out of position and rotates upward on the intact dorsal radiocarpal ligament.

Observers who have been interested in explaining the origin of these lesions have questioned a predisposition to dislocation in the form of anatomical irregularities and variations. Ettorre pointed out that the facets of the lunate bone may be irregular in robust subjects, and it is this type of person who is often exposed to the injury in his work. Delbet (quoted by Rauber, 20) gave importance to certain ligamentous variations as favoring dislocation. Schnek considered the exaggerated obliquity of the distal radial articular surface of importance in the genesis. Certain of these variations have been found in cases of dislocation, but also some lesions do not have such irregularities.

OCCURRENCE

These dislocations, although among the more common carpal injuries, are not of frequent occurrence, and the general practitioner is likely to see a case only occasionally. Rauber (20) called attention to the small number of 8 such dislocations that were found among 11,650 accidents. Mahorner and Meade noted only 2 cases among 649 fractures that had been treated at a male fracture clinic over a period of 2 years. Over a period of 27 years, only 24 cases have come to my attention.

CLINICAL FEATURES AND DIAGNOSIS

The importance of immediate recognition of these dislocations cannot be overemphasized. In the short period of time immediately following the injury, that is, to the limit of 2 weeks, reduction can usually be accomplished by conservative measures, whereas, later, reduction even by operative intervention might be too traumatic to be feasible. Should the injury go untreated or the treatment be inadequate, the function of the hand and wrist is likely to be permanently impaired through the damage to the soft structures and tendons.

Definite clinical and radiographic features are characteristic of these injuries. The patient usually gives the history of a fall on the outstretched hand. In fresh volar dislocation of the lunate bone there is an alteration in the contour of the anterior surface of the wrist, where in place of the usual concavity are found a prominence and thickening of the tissue. Quite typical is the position of slight flexion in which the majority of patients hold the fingers. Due to the blocking by the displaced lunate bone, the motion of the wrist is limited in flexion and the fingers cannot be fully extended. An important clinical feature is any evidence of irritation or damage of the median nerve from pressure of the dislocated bone; this may be in the form of a tingling sensation, paresthesia, or even excruciating pain.

The identification of the dislocated lunate bone on the palmar surface of the wrist under the flexor tendons is relatively easy by palpation, and the area is tender to pressure. On the dorsum of the wrist at the normal site of the lunate bone is a depressed area that admits the finger tip and is tender. If there is also fracture of the navicular bone, pressure in the anatomical snuff-box elicits tenderness.

A fresh perilunar dislocation of the carpal bones upward and backward is characterized by a prominent ridge running across the dorsum of the hand below the wrist joint. There is some swelling in this region; a deformation at the wrist joint may be noted; and if the infiltration is not too great, it may be possible to palpate the edge of the capitate bone on the dorsal surface of the wrist. It is not possible to palpate the lunate bone which remains in normal relationship with the radius. Motion of the wrist and fingers is limited and painful. In volar perilunar dislocations, the prominent ridge is found on the palmar surface of the wrist, and the distal edge of the lunate may be palpated on the dorsal surface.

The ultimate and detailed diagnosis of any of these dislocations rests with the roentgenogram. A true lateral view should be obtained to demonstrate the dislocated lunate bone or carpal bones, and anteroposterior views are needed to reveal any associated fractures. Stereoscopic studies give the most accurate picture of these injuries.

TREATMENT

Conservative Treatment. There is now general agreement that immediate manipulative reduction is the treatment of choice in fresh dislocations. A fresh dislocation is considered one that is less than 2 weeks' old. If reduction can be accomplished within this period, the procedure gives almost constant success.

Manipulative reduction of fresh dorsal perilunar dislocations: General anesthesia is used. The operator grips the patient's forearm between his own forearm and chest, placing his thumb against the displaced capitate bone. With his other hand the operator then grasps the patient's hand and increases the deformity while applying traction at the same time. The next step is to press with the thumb against the os capitate, with the traction still applied, and force the hand first into extension and then into flexion. The procedure is not unlike that used in the reduction of a Colles's fracture. The reduction is checked immediately by roentgenograms. The wrist is then immobilized in an anterior plaster shell extending from the knuckles to the elbow, in the position of flexion of from 30 to 40 degrees.

Fixation is maintained for 3 weeks in cases in which there are no associated fractures. Exercises and use of the fingers are begun as soon as the operative discomfort has subsided. After 3 weeks, the wrist is brought to the neutral position and thus maintained for 2 weeks longer. Still another week of fixation with the wrist in the position of slight hyperextension is advisable. In the later convalescence an adhesive strapping, a leather wrist-

let, or a bandage provides sufficient protection. Recovery is complete in 6 weeks or 2 months, but forcible hyperextension of the wrist, such as would be necessary in playing golf, should be avoided for at least 3 months.

Manipulative reduction of fresh volar dislocations of the lunate bone: General anesthesia is used. The operator grips the patient's forearm between his own forearm and chest, placing his thumb over the dislocated bone. With his other hand, the operator applies traction on the patient's wrist and dorsiflexes it. As the pocket for the lunate is opened up, the operator pushes the bone into place by pressure with his thumb. If, in this process further countertraction seems to be necessary, it may be provided by an assistant. Then, while the traction is still continued, the operator forcibly flexes the hand, and upon this maneuver the lunate is felt to snap into place. If reduction has been obtained, the hand will remain in the flexed position; if reduction has failed, the hand will spring back voluntarily into the position of extension. In the latter event, a second attempt at reduction may be made under fluoroscopic control, provided that no undue traumatizing force would be required to replace the lunate. Roentgenograms should be taken to check the reduction. The after-care follows along the same lines as that of perilunar dislocations.

Alternate methods of manipulative reduction: The socalled "broom-handle" method of reducing a dislocated lunate bone has been recommended by a few operators (22). It consists of forcing the lunate into place by rolling a piece of a broom-handle over the anterior surface of the wrist while the hand is being hyperextended under traction. This method is not generally recommended as it involves the danger of damaging the soft structures and it exerts a less direct force on the lunate.

Boehler's traction method of reduction in both the perilunar dislocation and dislocations of the lunate has given good results in the hands of some operators (1, 9, 17). This method consists of applying strong longitudinal traction on the outstretched fingers for a period of at least 10 minutes. If the lunate bone is displaced, this pull opens up the space to receive it, and the pressure of the flexor tendons forces the bone back into place. Following the reduction of the lunate bone, the wrist is immobilized in the neutral position. Following the reduction of a perilunar dislocation, the wrist is immobilized in the position of flexion and slight deviation to the ulnar side.

Operative treatment. The time limit for successful manipulative reduction is found to vary with the operator. Some surgeons are opposed to manipulative attempts later than 4 or 5 days after the injury. Most operators place a limit of 2 weeks on manipulative treatment, believing that after this period the force necessary to effect reduction would be too traumatic. Once luxation has taken place, the repair process sets in rapidly; ligaments contract, tissue becomes organized, and adhesions stabilize the bones in malposition. The space normally occupied by the lunate bone becomes filled with organized blood clot and fibrous tissue.

Followers of the Boehler traction method recommend attempting closed reduction as late as 3 weeks after the injury. In such cases the traction is prolonged, and even skeletal traction may be used. The advisability of using traction in dislocations of long standing is to be questioned. The pull must be strong and prolonged in order to overcome scarred tissue, and there is the danger of further damage to torn ligaments and capsule.

Operative treatment of dorsal perilunar dislocations. Operative indications are recognized under the following circumstances: A fresh dislocation that is associated with a great deal of damage to the joint structures or to the median nerve is best treated operatively, since attempts at manipulative replacement would cause further trauma. Fresh perilunar dislocations that cannot be reduced by manipulation are treated operatively. Open intervention is indicated in cases of more than 2 weeks' standing.

The same dorsal approach is used as in reducing dislocations of the lunate bone (described later). New tissue formation is removed from about the lunate bone. The carpal bones are brought into position by placing a blunt dissector on each side of the os capitate and using the lunate bone as a point

of leverage. The posterior ligamentous structures are repaired when possible in order to stabilize the reduction. When the dislocation is of long standing, that is, from 6 to 8 weeks or longer, it may be advisable to apply traction for a few days before the reduction, in order to overcome the contraction of the tissues and muscles and to pull the carpal bones slightly downward. Following reduction the hand is immobilized in the position of flexion, and the after-care is carried out along the same lines as that of manipulative treatment of perilunar dislocations.

Perilunar dislocations in elderly patients with arthritic joints, when complicated by excessive damage to the tissue structures and a disturbance of the circulation, are best treated by arthrodesis of the lunate, navicular, and capitate bones. Under such treatment the patient recovers a hand that is fitted for ordinary use and work, whereas following reduction of the dislocation, the wrist is likely to be painful and limited in motion.

Operative treatment of volar dislocations of the lunate bone: Operative intervention, in the writer's opinion, is indicated in the event of the failure of manipulative reduction, or in cases that are seen more than 2 weeks after the injury. Should operative intervention consist of reduction or of excision of the bone? For years there have been two schools of opinion on this question. In the past, excision has tended to be the procedure of choice, probably for two reasons. Excision is a far less complicated procedure than replacement of the bone. There was also the alleged belief that malacia or necrosis of the lunate bone eventually follows operative reposition. More recently, reports of successful surgical replacements have led to a revision of opinion in favor of operative reduction in selected cases (1, 2, 5, 6, 10, 11, 14–16, 18, 19, 20), although there is still a small group of operators who regard excision as the accepted method because of the danger of the development of arthritis from the traumatic dissection required in operative replacement (4, 8).

As to the likelihood of the development of necrosis following operative reduction of the lunate, it is impossible to judge the rôle of necrosis (1–4, 12, 20). There seem to be no published reports of the development of Kienboch's disease following operative reposition of the lunate, even when the bone was completely detached and the lesion treated late. No reference has been made in literature to the appearance of necrosis following manipulative reduction, even when the bone was apparently completely free. On the other hand, it would be logical to expect necrosis when the lunate has been cut off from its circulation, just as in cases of fractures of the navicular. Necrosis is a factor which must be considered in selecting the operative form of treatment for a dislocated lunate bone.

The majority of surgeons advise operative reduction in selected cases, using as a guide the time element and the local pathology. If the carpal bones show no gross changes, if the ligaments and tissues are little retracted, and if the lunate can be replaced without too much traumatism and maintained in position without flexing the hand acutely, operative reduction is indicated. The retention of the hand in acute flexion must be avoided because of the danger of the development of avascular necrosis during the long period of time that would be required for the hand to recover from this position. Operative reduction is more likely to succeed in incomplete dislocations than in complete luxations, due to the fact that there are sufficient ligamentous attachments to ensure an adequate blood supply to the lunate.

Surgeons differ in their opinion as to when the hope of operative replacement should be abandoned. The writer, as a rule, would not attempt operative replacement in a case of more than 6 weeks' standing, since after this period the reactive organization at the site of the injury would interfere with replacement. Some surgeons, on the other hand, attempt operative reduction within the 2 month period after injury, and others advise it as late as 6 months. Still others object to open reduction after the first 2 weeks, believing that later than this period it is difficult to suture around the lunate sufficiently to hold it in position.

Although hard and fast rules cannot be laid down, in general the following indications for operative reduction of the lunate may be recognized: Operative reduction is the treat-

ment of choice when a dislocation that is seen within 2 weeks of the injury cannot be reduced by manipulation with a minimum of trauma. Operative replacement is the best method of treatment in a dislocation that is seen between 2 and 6 weeks after the injury. In cases of more than 6 weeks' standing, operative excision of the lunate is indicated. When there is any question as to whether operative reposition or excision of the bone is preferable, it is better to remove the lunate.

The *technique of operative treatment* is as follows: After the administration of a general anesthetic, a tourniquet is applied on the forearm. A dorsal incision over the area of the lunate bone is used in any case in which reduction appears to be possible. This exposure is preferable to the anterior exposure for the following reasons: It leads directly down onto the lunate, avoiding tendons, vessels, and nerves, and requires no cutting of ligaments. Moreover, the dorsal approach avoids any difficulty in healing, such as the development of a keloid on the wrist, which may occur when the anterior approach is used owing to the flexed position in which the hand must be maintained following reduction.

The incision is about 2 inches in length. The fascia is divided and retracted, thus exposing the cavity of the lunate bone. The space to receive the lunate is prepared by applying traction on the hand and cleaning out the cavity. The lunate is then readily reduced. Any remaining remnants of the dorsal radiocarpal ligament are sutured. The fascia and skin are closed. The hand is then carried into flexion and maintained in the degree of flexion that ensures reduction. The after-care follows along the same line as that of perilunar dislocations reduced by manipulation.

In dislocations in which the question arises of excising the lunate bone, the anterior approach should always be used, as it is difficult to remove the bone through the dorsal exposure. An anterior incision 2 inches in length is made over the site of the lunate bone. The incision is carried down through the fascia and the anterior annular ligament. The flexor carpi radialis is retracted to the radial side, and the median nerve and palmaris longus and flexor sublimis and profundus digitorum tendons are retracted to the ulnar side. The space for the lunate is opened up by hyperextending the hand, and the cavity cleaned out. An attempt is made to slip the lunate into place, and if successful, the remnants of capsular tissue and the volar radiocarpal ligaments are sutured if possible. If reduction is not easily accomplished, the bone is excised. The annular ligament and fascia are sutured, and the skin wound is closed with interrupted silk sutures.

The hand is immobilized in the position of flexion, if reduction has been possible, and the same after-care is carried out as described under manipulative reduction of perilunar dislocations. If the lunate has been excised, the hand is hyperextended from 5 to 8 degrees and maintained in this position for 3 weeks. An anterior plaster shell extending from the knuckles to the elbow is used for fixation. Exercises of the fingers should be carried out during the period of immobilization.

The treatment of dorsal dislocations of the lunate bone. The unusual dorsal dislocation of the lunate bone is treated along the same lines as volar dislocations. If the case is seen early, manipulative reduction is attempted, the operator forcing the wrist into flexion, applying traction on the hand, and pressing the lunate bone back into position when the gap has been created to receive it. The wrist is then forcibly hyperextended. A posterior plaster shell extending from the knuckles to the elbow is applied with the hand slightly dorsiflexed. Immobilization is continued for 3 weeks. Use of the fingers is encouraged during the period of fixation.

Dorsal dislocations that are irreducible by manipulative methods, and cases of long standing, are treated by operative reduction or by excision of the lunate through the dorsal approach, the same indications being recognized, and treatment being carried out according to the same principles as outlined under the management of volar dislocations.

The treatment of dislocations complicated by fracture of the navicular bone. The treatment of these complicated dislocations depends upon the time element, the local pathological condition, and to a certain extent upon the age of the patient. If the case is seen early

and the accompanying damage is not severe, a fresh fracture-dislocation of either the perilunar type or of the lunate itself may be reduced by manipulation, the same maneuvers being carried out as in the reduction of a simple dislocation. The replacement of the navicular fragment takes place simultaneously with the replacement of the lunate bone. The hand is immobilized in as near the neutral position as possible, and the period of fixation is extended to allow time for healing of the navicular. At least 10 weeks are required, and even a period of 3 months may be necessary to obtain firm bony union. The fingers should be used freely throughout the period of immobilization.

In complicated dislocations of the lunate in which manipulative reduction is unsuccessful, and in cases of long standing, excision of the lunate bone and the proximal fragment of the navicular is the treatment of choice. Operative reduction in such cases is to be avoided because of the difficulty of execution and the danger of further interfering with the circulation. Following excision, an anterior plaster shell extending from the elbow to the knuckles, is applied, with the wrist in the position of 5 degrees' hyperextension. The patient is encouraged to use his fingers within a few days. Immobilization by means of the plaster shell is continued for 3 weeks, and then a protective adhesive strapping or a leather wristlet is worn for several weeks.

The older patient who sustains a complicated fracture-dislocation of this nature undoubtedly obtains a more useful hand if the wrist is arthrodesed. Manipulative reduction, operative reduction, or excision of the bones is likely to be followed by a periarthritis of the wrist.

PROGNOSIS

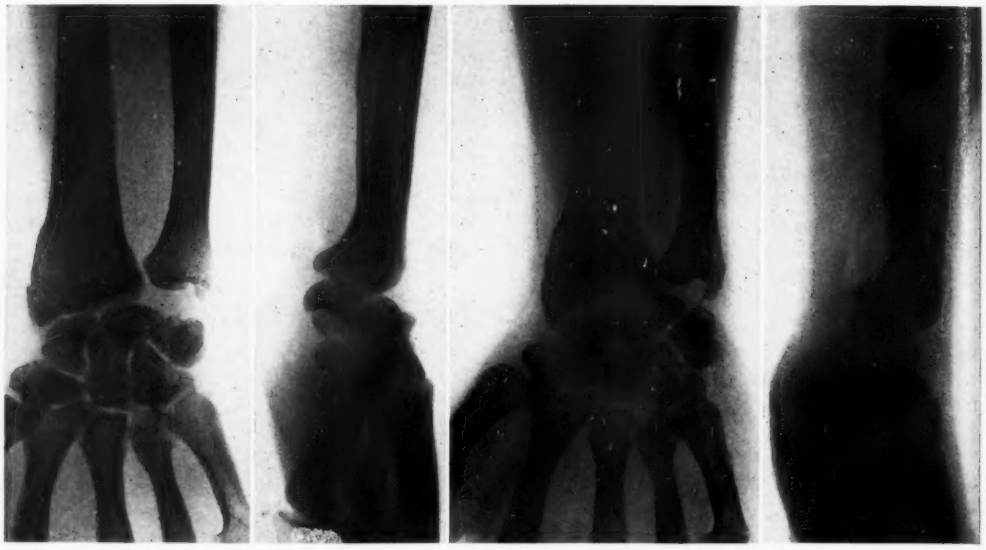
In general, the uncomplicated dislocation that can be reduced by manipulation is followed by complete recovery of function within a few months. Good results have been reported following operative reposition of the lunate bone. Rauber (20) has reported one of the largest series of operative reductions and such was his experience that he concluded excision of the lunate is often decided upon too quickly.

Fig. 5. H. S. a, left, A dorsal perilunar dislocation of carpal bones with an associated fracture of the radial styloid process, of 1 month's duration. b, Roentgenogram taken 2 months after manipulative reduction. Note the general atrophy which may be a part of these injuries.

The results of excision of a dislocated lunate bone, for the most part, are fairly satisfactory. Neither the function nor the strength is equal to that of the normal wrist, but the motion is satisfactory and the wrist and hand can withstand moderately heavy work. Pain is usually entirely relieved. Recovery in these cases depends to a great extent upon the presence or absence of a tenosynovitis of the flexor tendons, or damage to the median nerve, or periarthritis.

The prognosis in fresh dislocations complicated by a fracture of the navicular is not so favorable as in simple dislocations. Here the possibility of nonunion and necrosis of the navicular must be considered. A good recovery is more likely to be made following early manipulative treatment.

In older patients, and especially when there is any arthritic involvement, the prognosis in either the perilunar dislocation or luxations of the lunate must be guarded, regardless of the efficacy of treatment. Many of these dislocations are complicated by severe damage to the capsular tissue and ligaments, periosteal



a b

Fig. 6. W. K. a, Fresh dorsal perilunar dislocation of carpal bones complicated by fractures of navicular and both styloid processes. b, Roentgenogram taken 2½ years after manipulative reduction. Navicular remains ununited.

tears, small chip fractures, and disturbance of the blood supply, factors that cannot be eliminated by any form of treatment. It is not unlikely that a traumatic arthritis of the wrist and carpal joints may develop, causing the hand to be swollen and weak, and the motion limited.

In untreated cases the prognosis is poor as to the function of the entire hand. Motion of the wrist and fingers is limited due to the blocking by the dislocated bone or bones and to the presence of chronic swelling of the tissues. The fingers are usually permanently swollen, and the hand becomes atrophied from disuse. The patient complains of pain and numbness in the fingers, symptoms that are indicative of pressure on the median nerve.

CASE REPORTS

The series includes 24 cases. Twenty-three of the patients were men, a distribution that is to be expected since man is exposed to injuries in his work. The only woman was a circus performer. Seven patients had fallen from a height, 3 from stagings, 2 from trees, 1 from a window, and 1 from a trapeze. All had landed on the outstretched hand. Three patients had fallen on the ice; 1 had injured the hand in an automobile accident, 1 in an airplane crash, 1 in a motorcycle accident; 1 had caught the hand in a machine; and in 1 case the injury had been the result of the recoil of the crank of a motor. In the 9 other cases the origin of the injury was not recorded.

The right and left hands were equally involved. One case was bilateral.

Fourteen of the 24 lesions were of long standing, that is, from 3 weeks to 1½ years when they first came to the attention of the writer. Most of the patients had consulted a physician at the time of the injury, but they had received no definite treatment. One dislocation had been manipulated unsuccessfully 5 weeks after the injury. All 14 patients were complaining of continued disability due to pain, swelling, and limited motion of the wrist and hand. The delay in the treatment of 14 of 24 cases clearly brings out the fact that these lesions are either overlooked or the treatment is inadequate in the early stage.

The following dislocations are included in the series: 5 fresh dorsal perilunar dislocations

of the carpus, 3 dorsal perilunar dislocations of long standing, 1 fresh anterior perilunar dislocation; and 4 fresh volar dislocations of the lunate bone, 11 volar dislocations of the lunate bone of long standing.

Six of the 9 perilunar luxations were complicated by fractures, in 3 cases by fractures of the navicular either alone or in combination with fractures of the styloid processes, and in 3 cases by fractures of the styloid processes. Eight (1 bilateral case) of the 15 dislocations of the lunate bone were complicated by fracture of the navicular and 2 were associated with fractures of the styloid processes. The frequent occurrence of a concomitant injury in this series bears out the observation that a fracture is a common finding.

Six of the 9 perilunar dislocations were treated either on the same day as the injury or within a few days. Manipulative reduction was successfully carried out in 4 of the 6 cases. One case, following the failure of manipulative treatment, was reduced operatively, and open reduction was advised in the other case, but was refused by the patient.

The 3 perilunar dislocations of long standing, which were all of the dorsal type, were treated from 3 weeks to 1 month after the injury. Circumstances appeared to be favorable to manipulation in 2 cases, in 1 of which the procedure was carried out successfully. In the other case the closed reduction failed, and the dislocation was reduced operatively. The third case of dislocation was reduced successfully by the operative method.

In 2 of the 4 fresh volar dislocations of the lunate bone, all of which were seen within 2 weeks of the injury, an attempt at closed reduction was made, but in only 1 case was it successful. In the 2 other cases excision of the lunate was the primary treatment because of the extreme displacement of the bone.

The 11 volar dislocations of the lunate bone of long standing, that is, ranging over a period of from 3 weeks to 1½ years, were treated by excision of the bone. The majority of these cases were treated several years ago when excision tended to be the accepted treatment, and in the light of our present knowledge operative reduction undoubtedly would have been attempted in some of the cases. In 5 of these dislocations of long standing in which there was a concomitant fracture of the navicular bone, the proximal fragment of the navicular as well as the lunate bone was excised, and in 1 case (a bilateral case) both lunate bones and the entire navicular bones were removed.

Results. It was possible to check the results in 19 of the 24 cases after a considerable length of time, in the minimum after 1 year and in the maximum after 27½ years. The average period of observation was 8 years. All patients were requested to report for examination of their wrists, and, when this was impossible, to send a detailed account of the condition of their wrist and hand.

The 9 cases of perilunar dislocations were checked after a period varying from 1 to 13½ years. Two patients could not be traced. Five results were good, including 2 cases that had been treated by manipulative reduction (Fig. 5), 1 case that had been reduced operatively at the time of the injury, and 2 cases that had been treated by operation following unsuccessful attempt at manipulation. One of these patients is working in a metal plant and handling heavy coils. The patient whose wrist had been treated by operative reduction secured an excellent result, and when the wrist was examined 2½ years after reduction, it was withstanding heavy work in a defense plant. In another case the only defect is a limitation of 10 degrees in the extension of the wrist (Fig. 1). In 1 case that was treated by manipulation the alinement is good, but the navicular remains ununited (Fig. 6). In the remaining case, that of volar luxation, the result is unsatisfactory, the motions of the hand being limited and painful. This dislocation had been reduced successfully by manipulation at the time of the injury, but 3 months later the lunate bone had dislocated and excision was necessary (Fig. 2).

The 4 cases of fresh volar luxation of the lunate bone were checked from 7 to 21½ years after treatment. The patient who had been treated 21½ years previously had died. In the 3 other cases, 2 of which were treated by primary excision and in 1 of which excision followed unsuccessful manipulation, good results were obtained; 1 patient is a state

trooper, 1 is using his hand freely in working at a defense plant, and 1 patient who was a circus performer returned to the trapeze.

The 11 cases of dislocations of the lunate bone of long standing were checked from 6½ to 27½ years after operative treatment; 6 of these patients had been treated 20 years or more prior to the follow-up examination, and 4 others had been treated 12 or more years previously. Only 2 patients could not be traced. In 8 cases in which the lunate bone alone or both the lunate and the proximal fragment of the navicular had been excised, useful hands and wrists were obtained. Motion was limited in every case; the grip was from ½ to ¾ normal in all but 1 case; and there was some persistent weakness of the wrist. On the other hand, there was 1 excellent result in the case of a prizefighter who was able to return to the ring. There was another case of a dislocation that was complicated by a fracture of the navicular in which a perfect grip was recovered, and the patient now drives a heavy bus. One patient, who was traced after 21 years, had died, and his daughter wrote that the result had not been satisfactory because of a poor grip, pain, and coldness of the hand.

SUMMARY

In this paper an attempt has been made to clarify our conception of dislocations that involve the lunate bone. Two types of dislocation are recognized: the so called perilunar dislocation of the carpus, that is, the luxation of the carpal bones around the lunate, either dorsalward or volarward, and the dislocation of the lunate bone itself either dorsalward or volarward. From a therapeutic standpoint a sharp differentiation between the two types is of the greatest importance.

A plea is made for the recognition and treatment of these lesions in the early stage when conservative manipulation gives almost constant success.

From a study of the results in the 19 of 24 cases that it was possible to trace, it may be concluded that early manipulative treatment gives excellent results. Excision of the lunate bone, on the whole, results in a useful wrist and hand. In a few cases the function and strength were surprisingly good, but the majority of patients complained of weakness of the hand and were unable to make a tight fist.

Because so many of the dislocations of the lunate of long standing had been treated years ago when excision was the accepted method of treatment, the series fails to provide sufficient statistical material on operative reductions to permit judging the relative value of operative replacement and excision of the bone. In the 2 early perilunar dislocations that were reduced operatively, the results were excellent. The writer, today, would recommend operative reduction in uncomplicated dislocations of the lunate bone when manipulation fails or when the case is treated within 6 weeks of the injury. Dislocations of the lunate of more than 6 weeks' standing are best treated by operative excision. In dislocations of the lunate complicated by a fracture of the navicular bone, when manipulation fails or when the case of more than 2 weeks' duration, excision of both the lunate and the proximal fragment of the navicular is indicated. In perilunar dislocations of the carpus, operative reduction is indicated in fresh cases complicated by nerve damage, in cases in which manipulative reduction fails, and in cases of more than 2 week's duration.

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INJURIES OF THE VERTEX OF THE SKULL WITH SPECIAL REFERENCE TO THE PARACENTRAL LOBULES OF THE BRAIN

JOHN R. GREEN, M.D., and ERIC OLDBERG, M.D., F.A.C.S., Chicago, Illinois

COMPARATIVELY little information is available concerning the paracentral lobules of the cerebrum, and most of these data come from World War I. Disturbance of certain somatoautonomic functions of this region may be easily confused with those caused by lesions of the spinal cord. These factors and the increased incidence of such traumatic lesions of the central nervous system during wartime prompted us to review the literature and to report 2 remarkable cases of this nature.

ANATOMICAL CONSIDERATIONS

The paracentral lobules (Fig. 1) are formed by continuations of the precentral and postcentral gyri on the medial aspects of the brain. The anterior half belongs to the frontal lobe and the posterior half belongs to the parietal lobe. Each is bounded anteriorly, ventrally, and posteriorly by the end of the superior frontal gyrus, the cingulate sulcus, and the dorsally directed extension of the cingulate sulcus, respectively.

The cytoarchitecture of this region shows two principal areas (von Economo). The anterior portion is composed of typical precentral cortex with "pyramidization" of cells, with the exception that the Betz cells are largest and most numerous in the fifth lamina. The second to sixth laminae are composed of an unusually broad pyramidal layer, and the sixth lamina contains fusiform nerve cells. In the postcentral portion of the paracentral lobules, there is an indication of an inner and outer granular layer. The giant cells of Betz appear to be more dense and numerous and seem to be deeper than in the precentral gyrus.

Arterial blood reaches the paracentral lobule from a branch of the anterior cerebral artery. This vessel branches from a region near the middle of the corpus callosum, passing backward and upward to run for a short distance in the callosal-marginal gyrus and then it courses vertically upward to end in the substance of the paracentral lobule. In rare cases, the paracentral artery is actually the terminal portion of the anterior cerebral artery (Critchley).

Venous blood (Fig. 2) is collected from the paracentral lobules by precentral and postcentral veins of the superior cerebral system. Under normal conditions this blood empties either directly into the superior longitudinal sinus, or indirectly, into the sinus via a parietal venous lacuna. If this pathway should become gradually obstructed, a fairly efficient collateral circulation is maintained by veins which anastomose freely with the lateral cerebral veins. Of these collateral pathways the veins of Labbe and of Trolard are noteworthy; the former leads to the Sylvian system and cavernous sinus and the latter drains into the transverse sinus. The significance of the foregoing anatomical highlights will be discussed in subsequent paragraphs.

PATHOLOGICAL FEATURES

Necropsy and surgical reports concerning injuries of the paracentral lobules are meager. The majority of such studies were made on patients who suffered from wounds of the superior longitudinal sinus (Hershey, Holmes and Sargent, Kleist, and Bailey). Disturbance which followed a block of a parietal lacuna or the tributary veins to the sinus have been mentioned, as have cases in which there has been direct damage of the paracentral lobules (Holmes and Sargent).

The most common type of military injury occurs as the result of a gutter or tangential wound at the midline of the head. In civil life,

From the Department of Neurology and Neurological Surgery, University of Illinois College of Medicine, Illinois Neuropsychiatric Institute, and the St. Luke's Hospital, Chicago.

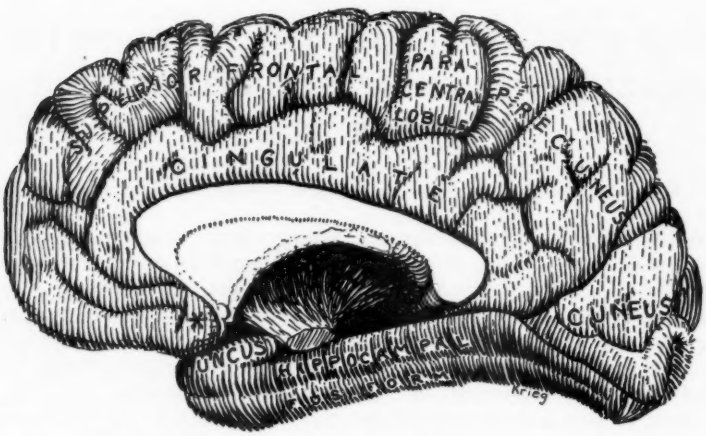

Fig. 1. Medial surface of cerebral hemisphere, illustrating location of the paracentral lobule (from Krieg's *Functional Neuroanatomy*).

the injury is more likely to be produced by a direct blow to the vertex. Although in many cases the outer table is undepressed and there is a depression of the inner table, in most instances both tables are depressed. This latter defect causes a spoon-shaped depression in the skull, and it is almost invariable that the injury is far more extensive than the roentgenograms of the skull indicate. Depressed fragments usually merely compress the sinus or its lacunae, but the walls of these vessels may be lacerated and fragments of bone driven into the adjacent paracentral lobules.

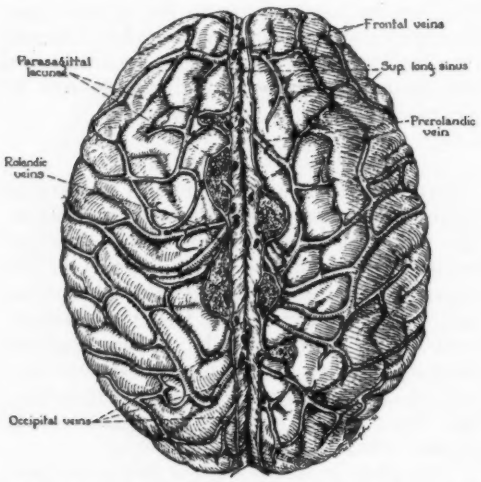

Fig. 2. Vertex of the cerebrum, showing the superior longitudinal sinus, lateral lacunae, and superior cerebral veins (from Bailey's *Intracranial Tumors*).

Exposure of the superior longitudinal sinus in such cases usually reveals the presence of a thrombus in the sinus. However, the venous obstruction is rarely complete because of the divisions of the sinus by irregular transverse trabeculations, its rigid walls, and the support offered to it by the dura mater. If the injury is more lateral, the thrombus may be limited to the venous lacunae beneath the lesion. Necropsy studies (Holmes and Sargent) showed that the superficial cortical veins which entered the sinus near the wound were thrombosed, and that there was congestion of the neighboring veins with edema of the adjacent brain. Section of such brains demonstrated edema and hemorrhages in the neighborhood of the wound, and, in some cases actual softenings near the medial surface. Occlusion of a cerebral vein has been shown to cause the following microscopic sequence: Congestion and thromboses in the cortex followed by sharply demarcated nets of hemorrhages, and finally, confluence of the latter (Putnam and Alexander). The process may progress to cause encephalomalacia, in severe cases, or may regress to recovery when the circulation of blood is re-established.

Circulatory disturbances in the paracentral lobules may be caused by a number of conditions other than traumatic lesions. Neoplasms, particularly the parasagittal meningiomas (Bucy), thrombosis of a superior cerebral vein without involvement of the superior longitudinal sinus (Waggoner, Merwarth, and Dowman) and thrombosis of the anterior cerebral artery (Winkelman, Ornsteen, and Wilson), are a few among such lesions.

PHYSIOLOGY OF THE PARACENTRAL LOBULES (FIG. 3)

As early as 1893, von Bechterew, working with dogs, localized the cerebral centers for the rectal and urinary sphincters in the sigmoid convolution, a region which is comparable to the paracentral lobule of man. Little information was contributed from this time until World War I, when Kleist and others observed cases of injury to the paracentral region which were characterized by a loss of control of voluntary micturition, paraplegia and little or no change of consciousness. The observations of Langworthy, Lewis, and Dees (19) suggested that one hemisphere was dominant in the control of the bladder and that this inhibitory center was close to the leg area. In apes it was found to be located at the top of the motor convolution near the nerve centers for the foot (Gruenbaum and Sherrington). In man the extirpation of one paracentral lobule (right or left) has no apparent effect on micturition (Bucy). This function seems to be subservient to bilateral control of this portion of the cerebrum.

With respect to the remainder of the mechanism, apart from the paracentral influence, the work of Hunsicker and Spiegel showed the existence of a double conduction system, pyramidal and extrapyramidal, of corticofugal impulses to the autonomic centers for the bladder in the spinal cord. Both centripetal and centrifugal pathways are situated in the dorsal half of the lateral column of the spinal cord near its periphery (Barrington). The lumbosacral segments of the spinal cord contain all of the nervous mechanisms for micturition, except those which decide whether its occurrence would be appropriate for the environment (Denny-Brown, 6). It is probable, however, that the sympathetic system exerts its influence solely through the medium of the circulation and the parasympathetic system through the innervation of the smooth muscle (Langworthy, 16).

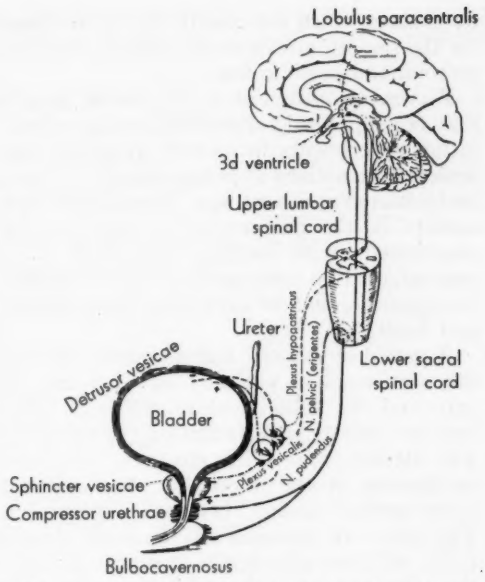

Fig. 3. Neural connections concerned with micturition (from L. R. Mueller in Kleist's *Gehirn Pathologie*).

The activity of some of the muscle which is innervated by the parasympathetic nervous system (e.g., the bladder and rectum), is closely correlated with the movements of striated muscle (Denny-Brown and Robertson, 7). These authors expressed the opinion that contraction of the external striated muscle sphincter of the bladder leads reflexly to suppression of waves of contraction in the vesical muscle and that voluntary micturition was begun by relaxation of the striated muscle of the perineum, followed by strong contraction of the vesical muscle. The rectum and pelvic colon, moreover, show spontaneous contractions which activity of the bladder tends to stimulate. The paracentral lobules apparently possess somatic and autonomic centers in close topical relationship. Thus, the skeletal muscle of the more distal segments of the lower extremities and that of the external sphincter of the urethra and anus is controlled

by centers which are closely related to those for the smooth muscle of the urinary bladder, rectum, and pelvic colon.

Waves of contraction in the vesical muscle may be suppressed voluntarily in man. Stimulation experiments in animals revealed that vesical contractions were suppressed, at times, and initiated at other times. Damage to these centers in the paracentral lobules may be manifested by an inability to initiate or to stop micturition voluntarily or by an inability to appreciate bladder distention (Langworthy and Kolb 23).

A period of "shock" follows interruption of the cortico-spinal pathway in man and in cats and the subsequent retention of urine may necessitate catheterization (Langworthy and Hesser, 17). With recovery, the tonic mechanism in the midbrain, when released from cortical control, becomes hyperactive. This causes an increased activity of the stretch reflex with incontinence or urgency or urination, the strength of the striated muscle of the external sphincter of the urethra being comparable to the increased tone of the muscles of the extremities.

The following cases illustrate clinical pictures of depressed fracture of the skull localized to the bilateral paracentral region.

CASE REPORTS

CASE 1. G. O., a 49 year old workman, was struck on the top of the head by a 20 pound iron bar which fell for a distance of about 35 feet. The injury occurred at noon on March 14, 1940. He is said to have been unconscious for a minute or two. He was examined 20 minutes after the injury by Dr. D. E. Dick (of Geneva, Ill.) who found him fully conscious and rational. He was admitted to the St. Charles City Hospital at 1:00 p.m.

There was a scalp laceration 6 centimeters long over the middle of the vertex of the skull, extending chiefly toward the left side. Upon the cleansing of this wound a fracture of the vertex of the skull could be seen, and a small amount of macerated cerebral tissue extruded. In addition to the above craniocerebral injury, the patient also complained that he could not move his legs and that they were numb. The knee and ankle jerks were present and equal. By about 5:00 p.m., motion was just beginning to return in the right leg and also some sensation. In order to treat properly the possibility of an associated back injury, several pillows were placed beneath the patient, thereby extending his back. The major complaints at this time were headache, fullness of the bladder, soreness of the back, and the motor and sensory disturbances of the legs.

He was seen by one of us (E.O.) in consultation at 8:30 p.m. the evening of the injury. At this time the patient was found to be lying in bed with reasonable comfort and to be perfectly conscious and rational. The head dressing was not disturbed. The patient was normal from the neurologic viewpoint, except for the lower extremities. Motion in the right leg was fairly good but the patient stated that he could not move the left leg at all. This paralysis involved the foot, lower leg, and thigh. Sensation, however, had returned in both lower extremities. The knee and ankle jerks were bilaterally present, equal, and active. There was no Babinski sign on either side. The patient stated that he had not voided since the time of the accident and that there was a feeling of distention of the bladder. He believed that he would be able to void spontaneously, however. He also complained of some pain in the lower lumbar region. Because of the presence of a compound skull fracture over the Rolandic area, it was believed that the initial paraplegia was cerebral in origin. However, it was also kept in mind that a craniocerebral injury might be complicated by an associated injury of the back. The treatment given was conservative.

By 10:00 p.m. it was seen that the right leg was slowly improving in strength. The patient complained rather bitterly about retention of urine and, accordingly, heat was applied to the pubic region. With considerable effort he was able to void spontaneously 700 cubic centimeters of urine, nearly 12 hours after the injury and after 6 hours of uncomfortable bladder distention. Again at 3:30 a.m. the next morning, he voided spontaneously, as he did normally thereafter. No abnormal depression of consciousness was observed at any time.

Portable roentgenograms of the skull and lumbar vertebral column were made. A U-shaped depressed fracture about 1 inch in depth over the vertex of the skull on the left side was seen. The wound was allowed to heal and operative interference was delayed. The patient improved slowly. Three days after the injury examination revealed that function had returned quite completely in the right leg, but that voluntary motion was still absent in the left leg. He suffered from periodic attacks of headache and vomiting during the first 5 days. On March 31, 1940 (17 days after the injury) motion in the left leg began to return. Flexion of the thigh and leg returned first, and 10 days later motion in the foot was possible for the first time since the injury. At the time of his discharge, on April 16, 1940, motion was normal in the right leg, sensation had returned completely, and the left leg was moderately paretic.

He was admitted to St. Luke's Hospital, Chicago, on May 6, 1940. The left leg had improved but still was weaker than the right and showed a Babinski sign and clonus of the ankle. Examination showed a depression of the vertex of the skull, a shallow, crater-like defect which measured 4 centi-

TABLE I.—SUMMARY OF POSTOPERATIVE RECOVERY, CASE 2

Date	General symptoms	Motion	Sensation	Bladder, rectal, sexual functions
3-16-42 (post-operative)	Intense suboccipital headache. Short periods of motor aphasia	Right central facial paresis. Tetraplegia (complete). Unable to raise head	Common sensation intact. Astereognosis bilaterally	Catheterized at 10 p.m.; 450 c.c. of urine. Bladder sensation normal; impotent
3-17-42	Headache	No change	No change	Voided spontaneously at 3 a.m., noon and 11 p.m. No residual
3-18-42	Headache. Intermittent pains of arms and legs	Facial weakness improved. Arms less rigid. Slight extension of right arm.	No change	Normal bladder and rectal function. Feels impotent still
3-20-42	Headache mild	8 a.m.: Voluntary motion in left thumb; partial extension of right arm. 8 p.m.: voluntary motion of both hands returning	Return of stereognostic ability in left hand	No change
3-21-42	No complaints. Profuse diaphoresis	All movements of hands and fingers; left, right. Flexion of right elbow	Return (partial) stereognostic ability in right hand	No change
3-24-42	Abdominal distention. Diaphoresis	Can turn head from side to side. Return of neck and head muscles	Stereognostic ability almost normal	No change
3-26-42	Mild diaphoresis	Shoulder motion on left side. Return of neck and head muscles	Normal	No change
4-1-42	No complaints	Able to sit up, hold newspaper and feed himself. Hands almost normal. Flexion of right thigh	Normal	No change
4-3-42	Mild diaphoresis	Slight flexion of left thigh. Slight extension of both thighs	Normal	Erection for first time since injury. Still feels impotent
4-6-42	Feels fine	Flexion of right leg	Normal	Feels potent
4-13-42	No complaints	Arms normal. Motion in trunk and proximal portions of legs fair. Slight flexion of left foot. No motion in toes. Bilateral ankle clonus for first time. Legs less spastic	Normal	Normal

meters in length. Roentgenograms were made (Fig. 4) and a depressed fracture was apparent in the vertex, near the midline and also slightly to the left. An area of about 6.5 centimeters of bone was seen to be depressed below the inner table.

On May 13, 1940 (2 months following the injury) the patient was taken to the operating room and a flap of scalp was reflected to expose the depressed fragment of bone. The bone was excessively vascular and overlay the sagittal sinus. Accordingly, a burr hole was made on the left side and this permitted the extraction of the depressed bone in two fragments. The fragments measured 3 by 2 by 0.5 centimeter and 1.8 by 0.6 centimeter. After some time, hemostasis was obtained and the wound was closed. The postoperative course was uneventful, the sutures were removed on May 16, 1940, and the patient was sitting up and walking about in the ward for 2 days before his discharge from the hospital on May 19, 1940.

Five months later examination showed improvement. The patient walked with a cane reasonably well and reported that he had been able to use a lawn-mower recently and was very pleased with his progress. His left leg was quite weak and spastic. He desired to return to work but was unable to do so because of his inability to climb a flight of stairs which led to his place of work. It was learned that on October 16, 1940, this patient had committed suicide.

CASE 2. E. A., a 34 year old Pfc. in the U. S. Army, was on leave when he was struck on the crown of the head by the edge of a plate glass window pane, which fell from a window 40 feet above. The injury was sustained at 11:00 a.m., March 9, 1942, and he was admitted to St. Luke's Hospital at 11:55 a.m. He was said to have been only momentarily dazed, to have lost about 250 cubic centimeters of blood from a laceration across the vertex of the scalp, and to have suffered immediate paralysis of both legs.

At the time of admission to the hospital the mental responses were normal and there was no headache or other discomfort. The blood pressure was 130/86. There was a jagged laceration about 10 centimeters in length across the crown of the head and a shorter one about 4 centimeters long on the forehead. The skin was very pale, cool, and moist. The cranial nerves were intact. Mobility of the neck was not ascertained because of a fracture or fracture-dislocation of the cervical region had not been ruled out. The speech and right arm were normal (he was right-handed). The left arm was spastic and somewhat rigid, but movements of the wrist and hand were preserved. Both legs were rigid in extension and all voluntary motions were lost. The deep reflexes in the left arm and both legs were increased. No pathological reflexes were elicited. There were equivocal and bizarre areas of hyperesthesia below the level of the clavicles. Four hours following the injury the patient complained of a strong desire to void but was unable to do so and 400 cubic centimeters of normal urine was obtained by catheter.

The immediate treatment consisted of bed rest, fixation of the head with sand bags in a position of

TABLE II.—DIFFERENTIAL DIAGNOSIS OF INJURIES OF THE SPINAL CORD AND BOTH PARACENTRAL LOBULES

Clinical features	Spinal cord	Paracentral lobules
Cause	Fracture or dislocation of vertebrae	Depressed fracture of vertex of skull near Rolandic areas
Motor signs (a) Early	(a) "Spinal shock" with flaccid paraplegia for days or weeks	(a) "Cortical shock" with transient flaccid paraplegia for hours or days
(b) Later	(b) Spastic or flaccid paralysis; signs usually reach maximum within a few hours	(b) Spastic paraplegia with early, remarkable rigidity. May develop triplegia or quadriplegia and rarely aphasia, over a period of days
	Distal segments of upper extremities and proximal segments suffer most and recover last	Proximal segments of arms and distal segments of legs suffer most and recover last
Sensory changes	May have complete loss of sensation in all modalities below level of lesion. Pain sensibility is almost always disturbed	Cortical type of sensory loss. Pain and temperature sensibility is rarely affected; astereognosis and atopagnosis are common
Autonomic signs: (a) Bladder (b) Rectal, and (c) Sexual	Early: Retention of urine and feces. Pain sensibility usually lost. Priapism common in severe injuries	Early: Retention or incontinence of urine and feces. Pain sensibility preserved. Priapism is uncommon
	Later: Slow recovery to normal or uninhibited cord reflex bladder. Gradual return of rectal and sexual power	Later: Rapid recovery of bladder function in most cases unless softening of both paracentral lobules occurs. Potency returns at about same time as sacral striated muscles
Lumbar Puncture: (a) Pressure	Normal	Normal or elevated
(b) Dynamics	Normal or incomplete or complete subarachnoid block	Normal
(c) Color	Clear bloodtinged or xanthochromic	Clear, bloodtinged or xanthochromic
Roentgenograms: (a) Skull	Normal	Depressed skull fracture over Rolandic areas
(b) Vertebrae	Fracture or fracture-dislocation	Normal; an associated cervical fracture may be present

slight extension and the administration of hypertonic fluids. Six hours following the injury the scalp was shaved and the wound cleansed and débrided. The entire crown area of the scalp was exceedingly edematous, the galea aponeurotica was apparently intact, and the examining physician in the emergency admitting room specifically stated that he had seen no evidence of skull fracture in the depths of the wound. Accordingly, following irrigation with physiological saline, he had applied approximately 2 grams of sulfanilamide and closed the wound with black silk sutures. The small laceration on the forehead was closed similarly. Tetanus antitoxin (1500 units) was also given. Portable roentgenograms of the cervical region were made and revealed no pathological changes.

Seven hours following the injury the patient again experienced a desire to void and spontaneously urinated 100 cubic centimeters, but from this time onward he was unable to void, in spite of the fact that he apparently possessed normal sensation in the bladder. He also complained of a feeling of impotency and of difficulty in defecation. The sphincter difficulties persisted unchanged until his operation of March 16, 1942, one week later.

On March 11, 1942 the patient complained of photophobia and of loss of all function of the left arm, with the exception of motion of his fingers. He still had neither mental symptoms nor headache. A lumbar puncture was made. The initial pressure was found to be 150 millimeters of water; the dynamics were normal. After the removal of 7 cubic centimeters of blood-tinged xanthochromic fluid, the pressure was 130 millimeters of water.

Four days following the injury, paresis of the right arm became apparent. Motion of the shoulder and elbow was lost, and only slight motion of the fingers was retained. The arm was also moderately spastic and rigid. Myoclonic contractions of the muscles of the right arm and both legs were frequent. There were no definite sensory changes, aphasia, nor loss of stereognostic sensibility.

Five days following the injury the patient experienced slight twitchings of the eyelid and corner of his mouth, on the left side, and also a period of inability to speak for approximately 20 minutes. He was unable to raise his head from the pillow and complained of photophobia. Tetraplegia was unchanged. The following day (Sunday, March 15, 1942) he appeared somewhat lethargic for the first time. There was also a partial facial paresis of central type on the right side and astereognosis of the right hand. Portable roentgenograms of the skull were made and showed a marked depressed fracture of the skull over the Rolandic area of the brain (Fig. 5). This fracture crossed the midline transversely and extended 3 centimeters to the right, 5 centimeters to the left, and about 8 centimeters anteriorly. The anterior portion of the fractured bone was depressed and broken into a number of fragments. The laceration of the scalp was fairly well healed and it was considered to be injudicious to temporize longer.

On March 16, 1942, utilizing local anesthesia, a horse-shoe-shaped scalp flap was made over the central region. On exposure of the affected area it was found to be depressed at least 2 centimeters and to be sufficiently shattered to be removable by blunt

Fig. 4. Roentgenograms of skull in Case 1. a, left, Posteroanterior view, and, b, lateral view. Note depressed fracture of vertex, near Rolandic area of brain.

dissection. Eight fragments were removed and these included pieces varying in size from 1.2 by 0.5 by 0.5 centimeter to 5.5 by 2 by 0.5 centimeter. When the bone had all been removed, the dura mater was found to be intact except over an area just to the right of the sagittal sinus. This area was about 3 centimeters in diameter, and macerated brain protruded through it. The wound was treated with sulfanilamide powder and closed with black silk suture material. A summary of the postoperative recovery is shown in Table I.

He was transferred from St. Luke's Hospital on April 20, 1942 to Fort Sheridan, Illinois. Re-examination (E.O.) on November 3, 1942, at the Billings General Hospital, Fort Benjamin Harrison, revealed the following findings: The scalp was well healed and there was a sunken defect about 3 centimeters in diameter over the vertex of the skull where the operation was performed. The patient stated that sphincter control was normal, as was his sexual power. The present vision was 20/20 in the left eye and 20/30 in the right. The patient felt that his hands were awkward in fine movements such as those used in dealing cards but were otherwise normal. The patient was using a brace on the left lower leg and ankle because of lack of power in the ankle causing a toe drop. The sensorium was normal.

Examination showed a well built man who apparently had gained some weight. He was alert and well oriented. There was no complaint of headache or dizziness. All cranial nerves were normal and all of the usual tests of the upper extremities were normally performed and the reflexes in these extremities were normal. The epigastric and abdominal reflexes were absent. The disability was confined to the lower extremities. There was no atrophy here but there was weakness, more marked on the left, and there was very slight motion of the left ankle joint. The knee jerks were bilaterally exaggerated with patellar clonus. The ankle jerks were within normal limits and there was no ankle clonus nor was there any Babinski or Oppenheim sign.

CLINICAL CONSIDERATIONS

Traumatic lesions which occur in the region of the vertex of the skull may injure the paracentral lobules directly or cause damage indirectly by means of venous obstruction. It is remarkable that the majority of cases (Kleist; Holmes and Sargent), like our own, show so little change in consciousness. This fact, in association with the loss of function of the legs, bladder, and rectum may initially suggest to clinicians the presence of pathology in the spinal cord, rather than in the cerebrum. The symptoms and signs of increased intracranial pressure are usually lacking, although many of the patients complain of headache and this may further direct attention away from the actual site of injury.

The site, severity, and extent of the motor symptoms are unusual and were first pointed out by Holmes and Sargent. In the upper extremities the proximal segments are the most severely affected and recover last. The muscles of the back are frequently involved, as in our Case 2, so that the patient can neither sit up nor move about in bed. The paralysis of the legs is the converse of that in the arms; thus, the distal segments suffer most and recover last. Damage to the nerve cells for the more distal segments of the legs is apt to occur first because occlusion of the veins is more apt to occur here in these smaller vessels, which drain from the apex of the hemisphere, and then to spread laterally to a varying degree. The marked rigidity of the affected extremities

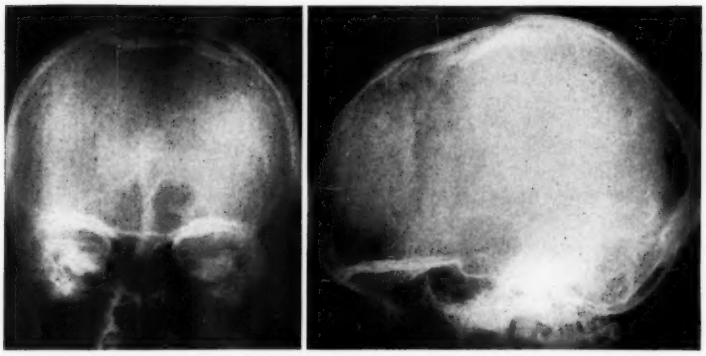

Fig. 5. Roentgenograms of skull in Case 2. a, left, Posteroanterior view, and, b, lateral view. Depressed, fragmented fracture of skull over Rolandic area of brain.

is a striking feature and was interpreted (12) to be secondary to pure cortical paralysis, unaccompanied by any effect of shock on the subcortical centers which control the tone of muscles. The more recent work of Kennard and Fulton concerning the function of area 6 (which is just anterior to the paracentral lobule) seems to offer the most plausible explanation of the muscular rigidity which is so characteristic of severe lesions in the paracentral region. Both of our cases showed a paraplegia at the onset. Improvement was rapid in Case 1; the right leg recovered quite completely within 3 days and the left leg improved slowly over a period of months. On the other hand, the injury was more severe in Case 2, and a quadriplegia developed within a few days following the initial paraplegia and was not relieved until after the decompressive operation had been performed upon the patient.

The association of motor and autonomic disturbances (e.g., dysfunction of urinary bladder, rectal, and sexual mechanisms) with these lesions has received little emphasis. World War I produced several outstanding reports. Although bladder dysfunction was noted in a certain number of the cases of Holmes and Sargent, rectal and sexual derangements were barely mentioned. The majority of the patients with disturbances of the bladder experienced some difficulty in micturition or even retention of urine (like our cases), but this almost always disappeared quickly. Incontinence was of less frequent occurrence. The usual sequence of events is as follows: first, retention of urine, which may disappear spontaneously as in Case 1, recover almost immediately after operation, as in Case 2, or be progressive, if there is more permanent damage. Following a short period of overflow incontinence, the bladder may recover or become uninhibited and hypertonic. It was concluded by Kleist that only if the deepest portions of both paracentral lobules or their efferent pathways are injured, can bladder disturbances be shown. He called attention to the disturbances of rectal function (involuntary movements or obstipation) in these cases. Similar symptoms and signs were noted by Wilson and in his Case IV, he records the paralysis of sexual function, in addition to the loss of use of the legs, bladder, and rectum. Potency, in his case, returned with the recovery of the sacral muscles whose nerve centers are represented in the paracentral lobules. Our Case 2 also regained his sexual powers at the same time as the recovery of the adjacent striated muscle.

From the foregoing discussion it is readily seen that many cases may offer some confusion in the differentiation of cerebral and spinal pathology (Table 11). Furthermore, a number of cases of injury of the spinal cord also have associated craniocerebral injuries, and vice versa. Figure 3 is a chart which outlines the differential features which may offer themselves.

CONCLUSIONS

1. Two cases of bilateral injury to the paracentral lobules of the brain are presented.

2. The influence of such lesions on sphincter control is reviewed and discussed.

3. The superficial clinical similarity of the symptoms and findings of spinal injuries and those of both paracentral lobules is pointed out, and suggestions regarding differential diagnosis are made.

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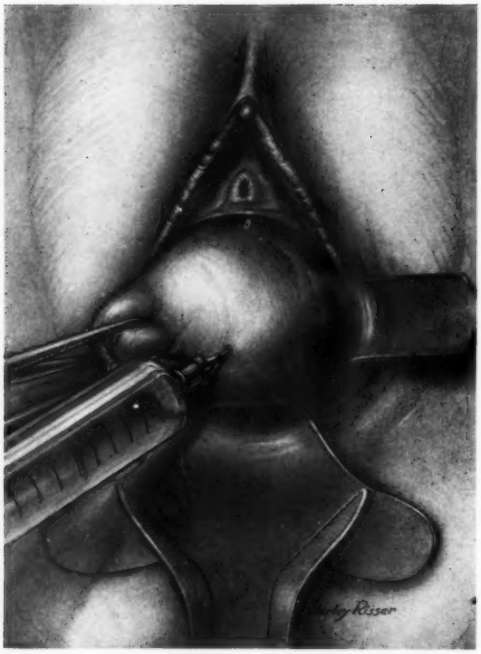

Fig. 1. Cervix exposed and grasped with tenacula.

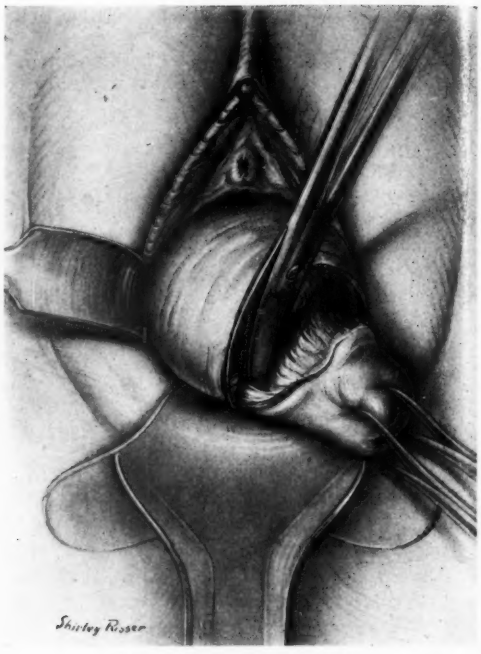

Fig. 3. Circumcision of cervix.

Fig. 4. The bladder is pushed off the cervix and laterally from base of each broad ligament.

Fig. 5. The peritoneum overlying rectum approximated to posterior vaginal wall by interrupted sutures.

Vaginal Hysterectomy.—Frederick Emmert.

VAGINAL HYSTERECTOMY

An Evaluation of Gellhorn-Emmert Modification of the Dickinson Technique in 600 Cases

FREDERICK V. EMMERT, M.D., F.A.C.S., F.I.C.S., St. Louis, Missouri

VAGINAL hysterectomy has been attracting a great deal of interest in this country in the past 10 years, a fact reflected not only in the fairly voluminous literature upon the subject, but also in the increased geographical distribution of the contributions.

Many of the discussions are repetition and invariably deal with the volume of patients operated upon, the proficiency of the operator, the low morbidity and mortality rate, the negligible blood loss, or the ease with which the pathological conditions are met.

Elaborate statistical data covering age incidence, indications for the procedure, postoperative complications, etc., are given in detail; however, the startling fact remains that, with two exceptions, this literature reveals a total lack of failures accompanying or following the procedure. Those individuals who fortunately did not contribute to the operative mortality rate of from 0.35 per cent to 0.45 per cent (Heaney) lived happily with no recurrence and without the subsequent development of such trivial affairs as urethrocele, cystocele, rectocele, or enterocele.

These exceptions, the contribution of George Gray Ward who reports a follow-up of his cases over a period of 16 years, and Phaneuf ably demonstrate that recurrences can occur even in the best of hands, and under these circumstances are we not justified in expecting recurrences in the hands of those possibly not quite so capable?

The history of vaginal hysterectomy is one of evolution, a transition through successive stages of accomplishment and perfection in overcoming the two great obstacles, namely: (1) lack of exposure of the operative site, (2) the obscurity of anatomical detail due to a bloody field.

From the Gynecological Service, St. Luke's Hospital.

Without an attempt to review the older literature, suffice to say, that in this country Christian Fenger in 1881 described his first case in detail; that gradual improvement in technique took place to 1915 when Charles Mayo described an operation designed to correct the vesical deformity accompanying uterine prolapse as well as to remove the uterus. This procedure has remained unchanged except for the modification as devised by Ward for prevention of enterocele.

The reports in literature deal mainly with the technique of the operation as devised by Mayo or a modification of the same, totally neglecting the undesirable sequelae occurring in a varying percentage of the cases. Apparently the follow-up of these cases over a period of 3 years or longer has not been reported, and without this valuable information, we are unable to evaluate the efficiency of a particular technique or to arrive at a basic conclusion as to its value in meeting the situation at hand.

What end-results have we a right to expect from an operative procedure? (1) No recurrence of urethrocele, cystocele, enterocele or rectocele, (2) preservation and maintenance of the vaginal canal.

It is the purpose of this paper to point out the end-results obtained from our technique, which has carefully been worked out over a period of 14 years, at the same time enumerating the course of failure and undesirable end-results of other procedures.

TECHNIQUE OF THE OPERATION

1. *Infiltration of the parametria.* The preoperative administration of morphine and hyoscine is used and the lower back is firmly strapped in order to prevent a sacroiliac strain from the extreme lithotomy position in which the patient is placed. The evening before, the patient is given a sterile water douche followed

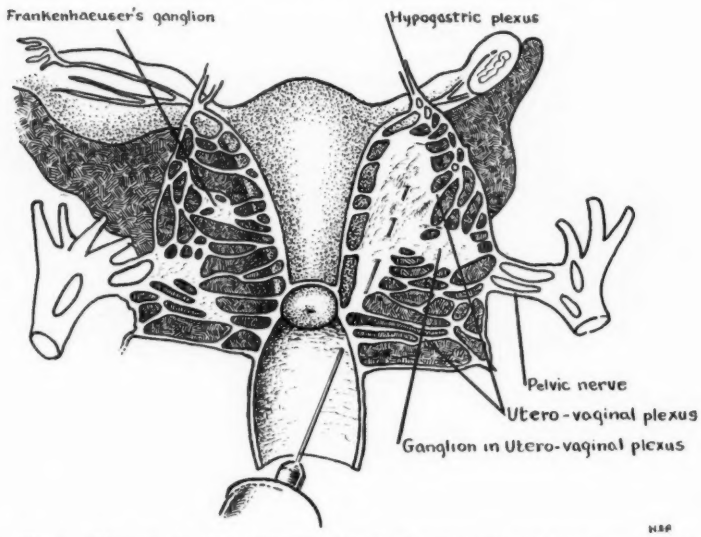

Fig. 2. Diagram showing infiltration block of parametria and large sympathetic ganglion of Frankenhaeuser.

by an instillation of phemerol. The cervix is exposed and grasped with tenacula, pulled down and to one side (Fig. 1). The needle of a 10 cubic centimeter syringe is inserted parallel with and alongside the cervix into the lateral fornix to a depth of 3 or 4 centimeters. Twenty cubic centimeters of 0.25 per cent novocain with adrenalin, 3½ drops to the ounce, are injected, while the needle is slowly withdrawn. The procedure is repeated on the opposite side.

Figure 2 shows diagrammatically how by this infiltration of the parametria the nerve supply of the uterus, particularly the large sympathetic ganglion of Frankenhaeuser near the base of the broad ligament, is blocked. After the two injections laterally, infiltration of the anterior vaginal wall to the urethra and posterior vaginal mucosa is done. Local infiltration causes a marked blanching of the tissues, which makes the dissection easier and helps produce complete hemostasis. With the use of the automatic continuous flow anesthesia syringe, there is little danger of injecting the fluid directly into the blood stream, for, as the plunger is pulled out, if blood is seen in the container, the needle must be withdrawn and reinserted.

2. Circumcision of the cervix. Demonstration of the vesicovaginal and vesicocervical spaces. With marked tension of the vaginal wall a complete circumcision of the cervix is made (Fig. 3). The level of the incision is slightly above the site at which the vagina becomes continuous with the cervix. This level may be recognized by the observation that the vagina above the portio is wrinkled, whereas the mucosa appears smooth over the portio. The entire thickness of the anterior vaginal wall is incised and the cut must be perpendicular to the surface of the tissues. If the incision is made to the required depth, the lips of the wound suddenly spread apart as the incision is completed. Through the wound may be seen the vaginal fascia, the surface of which is rough and covered with loose tissue with a characteristic red color. At the lateral edges of the anterior incision only the vaginal wall is incised, but in the middle portion the vaginal fascia should be divided transversely. As soon as this incision is made, the vesicovaginal space is entered. The supravaginal septum extending from the bladder to the cervix now comes into view. It is also transversely incised, thus opening the vesicocervical space. With counterpressure by the anterior bayonet

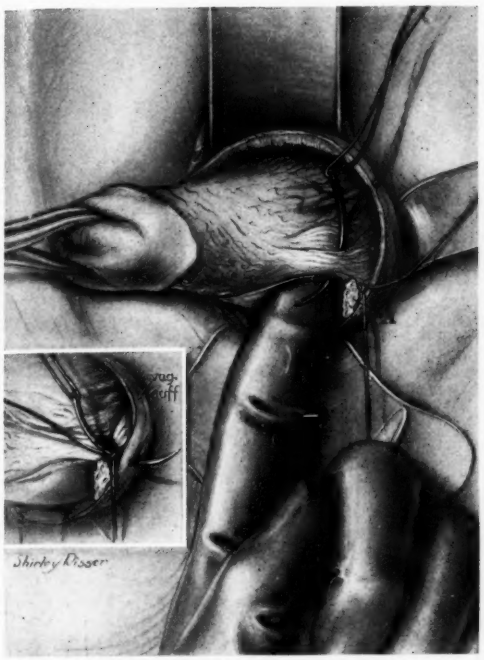

Fig. 6. Base of broad ligament exposed; left uterosacral ligament has been ligated and cut.[1]

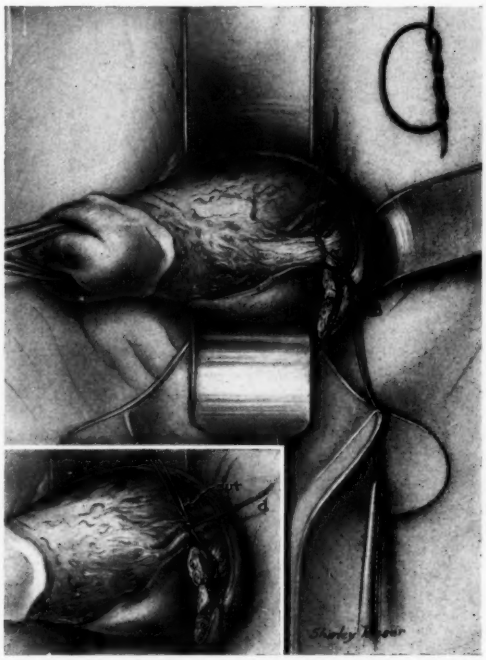

Fig. 7. Inset shows how vessels are ligated with a square knot. Loose end of ligature *d* held by Kelly clamp.

retractor, the bladder is pulled away from the cervix in this area. The bladder is then pushed off the cervix (Fig. 4) and laterally from the base of each broad ligament. The lateral boundaries of the vesicocervical space are the bladder septa, that is, the vesicouterine ligaments, which stretch backward from the bladder to the Mackenrodt ligament. On each side the uterine vessels lie, and may be seen, mesial to the bladder septa, extending downward at the edge of the uterus. The vesicocervical space may be opened upward as far as the anterior peritoneal fold. If the anterior bayonet retractor holds the bladder back, it is possible to see the edge of the peritoneal attachment to the anterior wall.

3. (*a*) *Posterior cul-de-sac opened exposing fundus uteri;* (*b*) *peritoneum overlying the rectum is sutured to the posterior wall;* (*c*) *left uterosacral ligament ligated prior to cutting.* The cervix is pulled toward the symphysis. Counter-pressure is made by the right and left Pfannenstiel retractors and the posterior weighted retractor, thus causing tension of the posterior vaginal fornix. To open the posterior cul-de-sac, the vagina and its fascia must be completely incised in the middle third of the posterior incision. At each side, where the anterior and posterior incision meet, it must be remembered that only the vaginal mucosa is incised, for if the incision is made deeper in these areas the veins of the vaginal plexus which lie in the vaginal fascia are cut, resulting in unnecessary bleeding. The peritoneum of Douglas' pouch is now transversely incised; it is recognized by its white translucent appearance. The peritoneum overlying the rectum is approximated to the posterior vaginal wall by interrupted sutures (Fig. 5). They prevent troublesome bleeding from the posterior vaginal wall supplied by the hemorrhoidal vessels. The sutures are left long to serve as guides later in the operation. With the cervix still on tension two strong fibrous bands can

[1]Drawings reproduced through courtesy of the *Surgical Clinics of North America.*

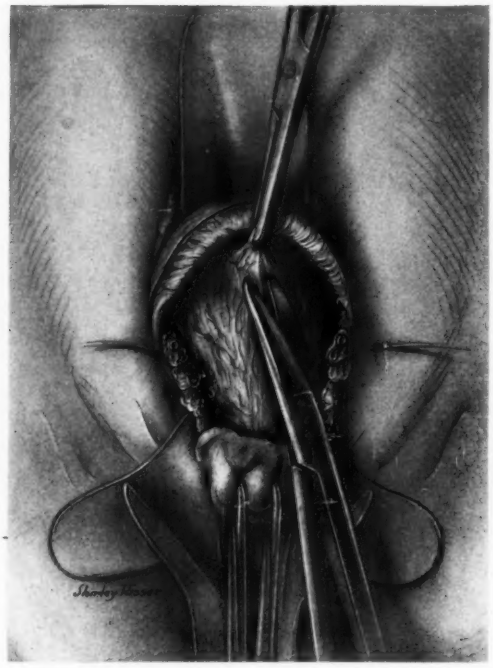

Fig. 8. Cervix pulled downward. Anterior peritoneal plica grasped with curved forceps, held up and incised transversely between uterus and clamp.

Fig. 9. By means of the left original suture, two additional looped stitches are placed in the avascular portion of broad ligament.

be seen converging toward the uterus. These are the strong uterosacral ligaments. They are clamped and the left uterosacral ligament is ligated and cut. A full length suture of one 40 day catgut is used, the free end being left fairly long.

4. Incision of the parametrium. Continuing with the long suture the cervix is pulled toward the right, thus exposing the base of the broad ligament. As pointed out before, the left uterosacral ligament has been ligated and cut (Fig. 6). The left forefinger is inserted in the posterior cul-de-sac in order to guide the needle through the base of the broad ligament. After the suture has been tied, the needle anchors this stitch to the adjoining vaginal wall. The end of the suture is secured with a curved clamp. The cervix and suture are pulled in different directions and a cut is made between. Figure 7 shows how the stitch is continued upward to ligate the left Mackenrodt ligament and the succeeding portion of parametrium; the suture is looped twice and kept taut by the assistant. This serves as a retractor and prevents slipping. The ligated tissues are cut away from the uterus about 1 centimeter mesial to the ligature and in a plane parallel with it. The second loop stitch is close to the uterine vessels.

The vessels are clearly identified and with the left index finger in the pouch of Douglas at the edge of the uterus, which is pulled downward, the needle is inserted mesial to the attachment of the bladder septum to Mackenrodt's ligament. It passes from the vesicocervical space backward around the upper portion of the ligament and uterine vessels. Figure 7 inset, illustrates how the vessels are ligated with a square knot and the loose end of the ligature *d* is held by a Kelly clamp. One strand of the loop is cut. The opposite side is done in the same fashion.

5. Opening of the vesicouterine peritoneal plica. Separation of the adnexa from the uterus.

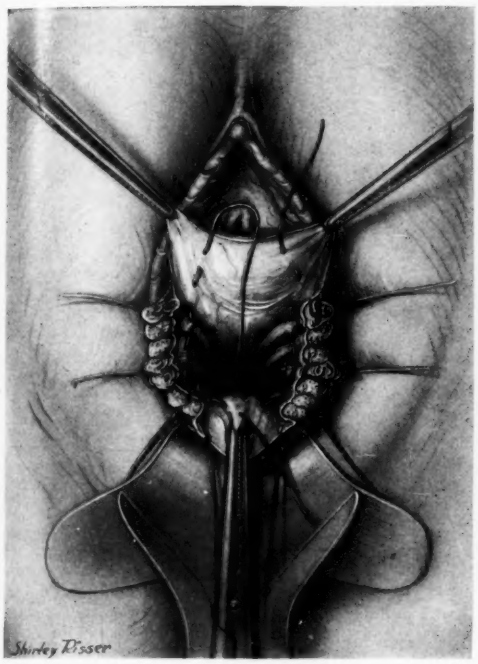

Fig. 10. Closure of peritoneal cavity with pursestring suture.

Fig. 11. Separating anterior vaginal wall from bladder by blunt scissors dissection.

The cervix is pulled downward and the anterior peritoneal plica is grasped with a curved forceps (Fig. 8), held up and incised transversely between the uterus and clamp. The opening is enlarged by cutting the peritoneum laterally. The bayonet retractor is inserted into the peritoneal cavity thus holding the bladder back.

By means of the left original suture, two additional looped stitches are placed in the avascular portion of the broad ligament (Fig. 9), and the tissue is cut. Locked sutures include the tube and round ligament. The same procedure is done on the opposite side and the uterus is removed with or without the adnexa.

6. Closure of the peritoneal cavity. Traction is placed on the ligatures of the adnexal stumps and the parametrial vessel bundle; also the peritoneum of the bladder and rectum is pulled forward. In this manner the entire border of the peritoneum remaining after the extirpation of the uterus may be well exposed. The peritoneal cavity is now closed by a pursestring suture (Fig. 10), whereby the stumps of the following ligaments—round, Mackenrodt's or cardinal, broad and uterosacral—are placed extraperitoneally.

7. Care of the bladder. The anterior vaginal wall is next separated from the bladder by blunt scissors dissection (Fig. 11) and suitably resected, if redundant. The bladder is exposed and the plication of the bladder wall is done. The bladder fascia is then approximated (Fig. 12 inset). The needle on ligature of the stump of the round ligament is placed through the subpubic fascia near the upper angle of the wound on either side (Fig. 13). When these two ligaments are in place, the bladder is pulled backward and out of the way. The round ligaments are thus interposed between the bladder and anterior vaginal wall. Interrupted sutures approximate the base of Mackenrodt's ligaments and the uterosacral ligaments. Through-and-through interrupted sutures of vaginal cuffs and stumps of the broad ligaments are seen in the inset (Fig. 13).

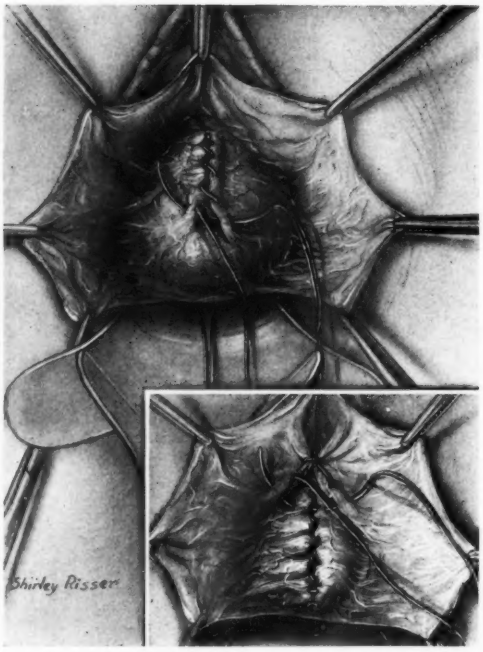

Fig. 12. Exposure of bladder, approximation of bladder fascia, inset.

8. Colporrhaphy plastic of the perineum. The posterior vaginal wall is caught with a forceps high in the vagina. The edges of the vulva are grasped with a tenaculum on each side (Fig. 14), the posterior vaginal wall is infiltrated, and the mucocutaneous junction is incised with blunt scissors. The posterior vaginal wall is next incised and dissected free from the underlying fascia (Fig. 15). The fascia over the rectum is plicated, the levator ani muscles are brought together in the midline with interrupted sutures, and the overlying fascia is approximated with a continuous suture (Fig. 16). Interrupted sutures of one 20 day catgut are used for the vaginal mucosa and black silk for the transverse mucocutaneous margins. This completes the 4-layer method of Studdiford (Fig. 17).

POSTOPERATIVE TREATMENT

A mushroom catheter is introduced into the bladder to remain 24 hours. A fracture board is placed beneath the mattress to relieve the severe backache that invariably follows the extreme lithotomy position during the operation. As a rule, one or two hypodermic injections of dilaudid are all the sedative that is required. The head rest is raised the second day after operation and a soft diet is tolerated. A light to the perineum is used twice a day for 45 minutes in order to keep the parts dry. The patient is out of bed on the 10th day.

DISCUSSION OF THE TECHNIQUE

This, in general, is the plan of the operation. Occasionally, slight additions or alterations are needed. A narrow vaginal outlet requires a Schuchardt incision. A uterus too large to be removed in the manner described, may have to be made smaller by bisection or morcellation, or the fundus may have to be luxated outward before the upper portions of the broad ligaments can be ligated.

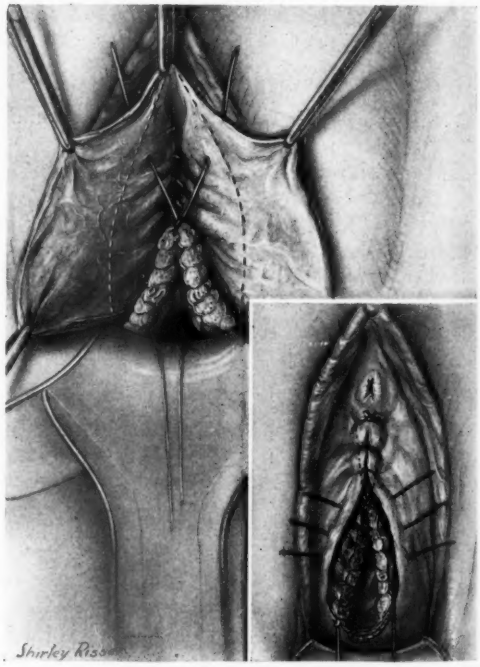

Fig. 13. Needle on ligature of stump of round ligament placed through suprapubic fascia at upper angle of wound. Through-and-through interrupted sutures of vaginal cuffs and stumps of broad ligaments.

However, there are certain advantages in our technique that should be emphasized.

1. The effect of the local anesthesia is very striking throughout the operation. Circumcision of the cervix and cutting through the parametrium is entirely painless. As the uterus follows the pull of the tenacula and direct traction is exerted on the round and infundibulopelvic ligaments, some pain is experienced in a certain number of cases. Fortunately this pull is of short duration as the adnexa are quickly removed. The pain is probably due to the fact that the traction on the ligaments also involves the parietal peritoneum which is highly sensitive as we know from the fundamental work of Lennander. It is very easy at this stage of the operation to give the patient a few drops of ether or a few whiffs of gas. The remainder of the operation, that is, the closure of the peritoneum, the interposition of the round ligaments and the approximation of the broad ligaments and vaginal mucosa, is entirely painless.

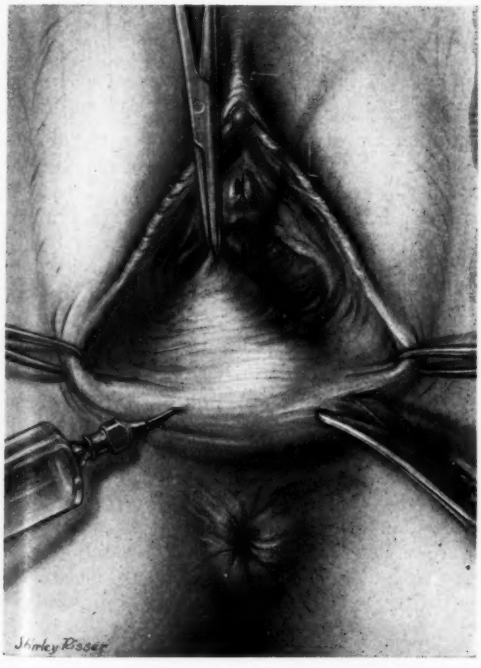

Fig. 14. Colporrhaphy plastic of perineum.

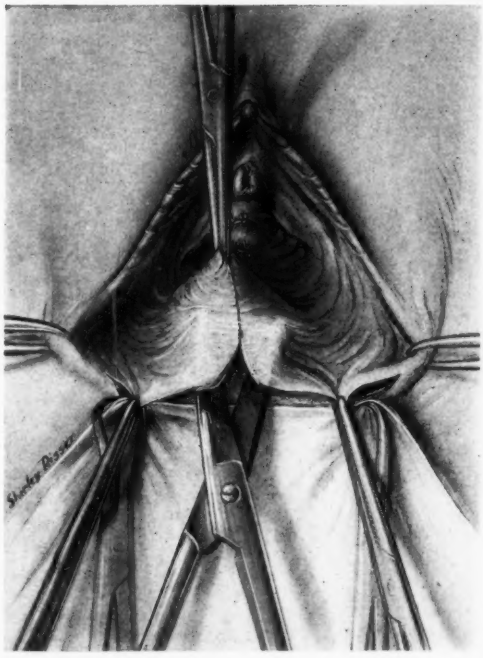

Fig. 15. Posterior vaginal wall incised and dissected free.

Thus, under local anesthesia, it entirely loses the character of a major operation; there is no shock to the patient, very little loss of blood, if any, and, most important, is the ease with which the tissues are identified and dissected. Systemic complications such as diabetes, cardiorenal disease, active tuberculosis, which might contraindicate a general narcosis, or old age and extreme obesity, which render any operative intervention extremely hazardous, present no objections.

2. It permits an extension of the usual indications for vaginal hysterectomy, in that descensus and prolapse are made at the beginning of the operation as the lateral and posterior uterine attachments are cut. In other procedures, as soon as the bladder is pushed back from the cervix, the anterior peritoneal fold is incised and the uterus is luxated. We feel that this has very definite disadvantages and as described in our technique the anterior cul-de-sac is not opened until the uterine vessels are cut and ligated and the posterior and lateral

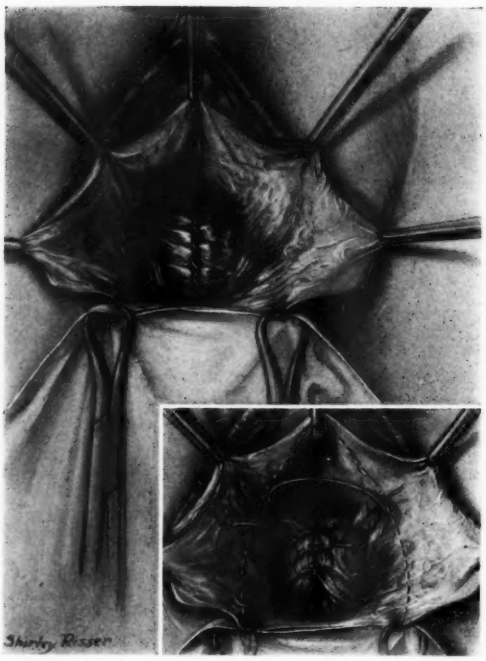

Fig. 16. Fascia over rectum plicated, levator ani muscles brought together in midline with interrupted sutures and overlying fascia approximated with continuous suture.

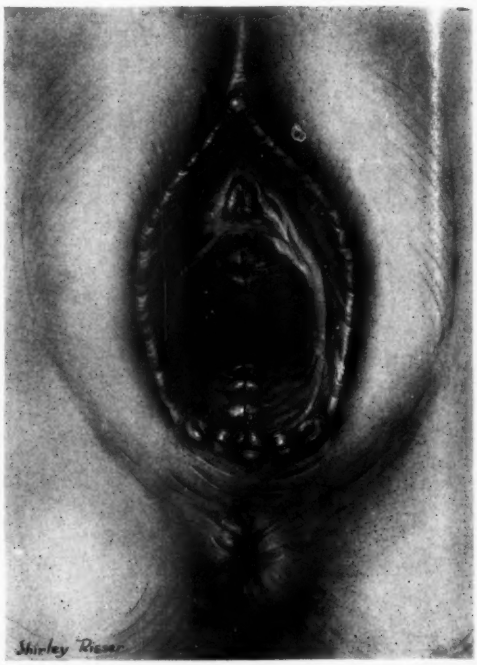

Fig. 17. Interrupted sutures of catgut for the vaginal mucosa and black silk for transverse mucocutaneous margins complete the 4 layer method of Studd.ford.

attachments up to the avascular portion of the broad ligaments are cut.

3. By following the procedure of interposing the round ligaments between the bladder and anterior vaginal wall it is nearly impossible for a recurrent cystocele to take place. This is certainly a distinct advantage over other procedures in which very little attempt is made to prevent herniations of the bladder. In the Mayo technique, Counseller states that the operation "brings the stumps of the broad ligaments extraperitoneally and at the same time uses them as a supporting base for the bladder." To my mind this is the weak point of that procedure. It is anatomically unsound and a vesical prolapse between the pubic rami and upper portions of the broad ligament can occur.

4. The prevention of enterocele is accomplished by obliterating the pouch of Douglas and shortening the uterosacral ligaments. Ward noted that in marked prolapse there is an extensive stretching of the uterosacral ligaments, and frequently a hernia of the posterior vaginal fornix or enterocele occurs. Many procedures fail to make any attempt to prevent these unpleasant complications.

5. Lastly, by our technique a moderately deep vagina is assured. This is certainly not true following many cases of vaginal hysterectomy by other techniques, particularly for genital prolapse in which one can assume that many vaginal vaults are more or less flushed with the introitus.

RESULTS

The 600 cases of vaginal hysterectomy reported in this series over a period of 14 years were private cases of Dr. George Gellhorn and myself and cases from the Barnard Free Skin and Cancer Hospital. The technique used in this series by ourselves or associates was the one here described. There was a strict follow-up of all cases in private work over a period of

TABLE I.—FOLLOW-UP RESULTS 1928–1942 INCLUSIVE

	Cases	Per cent
Total private cases—Follow-up of 3 years or longer	502	
Total Ward cases—Follow-up of 6 months or longer	98	
Satisfactory results	524	87.33
Recurrences		
1. Cystoceles	36	6
2. Rectoceles	28	4.6
3. Enteroceles	5	0.83
4. Incomplete vaginas	5	0.83
5. Urethrocele	2	0.33
Unsatisfactory results	76	12.66
Ward's statistics		
No data given for recurrent cystoceles and rectoceles except enteroceles following Mayo technique—		
1918–1934	82	
Enterocele developed postoperative	15	18.2
1923–1934	40	
Enterocele developed postoperative	4	10.0
(After improved technique of obliteration of cul-de-sac and suturing uterosacral ligaments.)		
Phaneuf statistics		
Vaginal hysterectomy for uterovaginal prolapse following Mayo technique—		
1936	56	
Recurrences	4	
(1) Enteroceles, 1 large, 1 small	2	
(2) Enterocele, small rectocele, some incontinence of urine	1	
(3) Small cystocele and rectocele	1	
Unsatisfactory results	4	7.1

The recurrences of all unsatisfactory conditions in our series is 76 or 12.66 per cent. However, of this number 64 or 10.6 per cent, have been cystoceles or rectoceles. We have no comparative series with which to deal. Accepting the recurrences of enterocele upon which we have comparative statistics, we have demonstrated 5 cases or 0.83 per cent in our series as compared to an 18.2 per cent occurrence in 82 cases between 1918 and 1934 or an occurrence of 4 cases or 10 per cent after a modification and perfection of the technique. I believe that we are justified in the conclusion arrived at from this statistical basis that the tendency is at least ten times greater for a recurrence of an enterocele following the Mayo technique with the Ward modification over our method.

3 years or longer, and from the clinic over a period of 6 months or longer. Our results with those of Ward and Phaneuf are summarized in Table I.

CONCLUSIONS

The literature dealing with vaginal hysterectomy, with possibly one exception, has demonstrated the lack of follow-up information and almost complete absence of statistics upon which to base logical conclusions as to the efficiency of a procedure.

The details of our operation are described and depicted in this paper. This is to justify the assumption that our technique is the one of choice, not only through the ease of accomplishment, but likewise the lack of recurrence of undesirable sequelae. The number of cases is of sufficient magnitude to warrant a basic supposition of reliability in our statistics.

It is with confidence that a greater interest in this procedure will be shown by a betterment of these statistics.

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SURGICAL EXPERIENCES WITH ABDOMINAL WOUNDS IN THE NORTH AFRICAN CAMPAIGN

EDWARD L. ROHLF, M.D., Captain, M.C., A. U. S., Waterloo, Iowa
JOHN M. SNYDER, M.D., Lieutenant Colonel, M.C., A. U. S., Slatington, Pennsylvania

BATTLE casualties from abdominal wounds have always had a rather high mortality. In World War I the majority died in the field (4) although considerable progress had been made in their management by the end of the war. However, Rippy reports that even in civilian life there is a mortality of 55 to 60 per cent in individuals under 40 years of age. The lowest single yearly figure was 41.3 per cent. Hamilton and Duncan have likewise reported a 51 per cent mortality for gunshot wounds of the abdomen.

In modern warfare Gordon-Taylor (5, 6) reported 50 per cent recoveries for abdominal injuries but with mortality variations from 40 to 80 per cent when various viscera were involved. The Germans have reported a 66 per cent mortality (10) and Ascroft has reported a 37.5 per cent postoperative death rate for abdominal wounds treated in one of the British mobile surgical units. In the Spanish war there was almost a 100 per cent fatality in patients with wounds of the colon (2).

The authors have happily found in their experience that with the full employment of the various newer therapeutic measures now available, both before and after operation, the mortality figures for the abdominally wounded from the American Army in North Africa did not approach the figures quoted here. Ample credit must be given also to the efficient medical evacuation rendering surgery available without undue delay. The over-all mortality of all cases seen by the authors, both operable and inoperable, i. e. moribund, has been 20.41 per cent. Postoperative mortality for those operated on in one evacuation hospital was 11.94 per cent. No patients were transported after operation until their condition warranted and none died therefrom en route to the rear through supporting larger evacuation hospitals. It is granted a certain ultimate additional mortality may accrue due to late complications and secondary surgical procedures, as closures of colostomies.

SOURCE OF ADMISSIONS

The hospital in which the patients were treated whose records are herein reviewed entered the African Campaign with the invasion forces as a surgical hospital. Although later reorganized after the Southern Tunisian campaign as a semi-mobile evacuation hospital, it functioned throughout the Tunisian Campaign, from early January to the close of the Campaign in May, in a forward position. Usually located from 7 to 35 miles behind the actual front lines, the distance varying with tactical considerations, its employment was such that a good cross-section of the type of abdominal casualties that may be expected in modern military campaigns was thus obtained.

No attempt will be made here to explain the system of Army evacuation. However, it should be noted at this time that en route to our hospital, besides routine morphine administration many of the injured had received amounts of blood plasma intravenously, varying from 250 to 1,000 cubic centimeters, depending upon their degree of shock. This undoubtedly allowed many patients to be transported to the hospital who otherwise might well have died en route, or developed such severe shock that the condition was irreversible on admission. A certain small group of patients included in the present series had undergone emergency surgical operations in the clearing stations forward of this hospital. On occasion, perhaps as the result of a change in tactical situation, these patients were transported to us at an early postoperative date. Admitted at times still under anesthesia, at times in severe irreversible shock, their progress was not infrequently one of rapid decline and fatality despite the utmost of supportive

measures. As will be shown, postoperative patients who have recently undergone celiotomy do not tolerate early transportation.

CLASSIFICATIONS OF ADMISSIONS

There were 98 patients with penetrating abdominal wounds admitted to this hospital during the campaign. The incidence was a good deal lower than was expected. A comprehensive study of patients with chest injuries admitted to this hospital was made, and the incidence of the abdominal wounds and chest wounds was practically identical.

Three types of abdominal cases admitted to this hospital will be considered in this paper. Those who were operated on in this hospital, those on whom surgery had been done at a forward medical installation, usually by clearing station personnel or an attached auxillary surgical team, and lastly, those who were treated conservatively without surgery.

CAUSATIVE MISSILE

The causative missile in abdominal wounds has a direct bearing on the mortality rate and type of wound but little influence on the treatment. The causative agents encountered were missiles from small arms fire, including strafing from the air, fragments from high explosive shells, and bomb or land mine fragments. There was not one bayonet wound of the abdomen in this series.

Bullets from small arms fire in most instances caused a penetrating wound of the abdominal wall, sometimes a through and through wound with a perforating type of intra-abdominal injury. With this type of abdominal wound, associated extra-abdominal wounds were unusual.

High explosive shells, bomb or land mine fragments caused both penetrating and perforating (through and through) wounds of the abdomen and in addition, in some cases, marked destruction of abdominal parietes. The type of intra-abdominal injury was usually unpredictable. It might be a simple perforation of the viscus, multiple perforations, or almost complete mutilation and destruction of the involved organ or organs.

Associated injury in addition to that produced by the explosive fragments might be caused by concomitant blast. In a few instances, clothing or some other foreign body was also carried in by the initial missile. Many patients wounded by shell, bomb, or mine fragments had other serious wounds incurred simultaneously, which with the abdominal wound markedly influenced the prognosis, morbidity, and mortality. Whereas in civil life, a traumatic intra-abdominal wound is usually the only problem for the surgeon to deal with, in war casualties, associated injuries in addition to the abdominal wound are the rule rather than the exception.

FACTORS INFLUENCING MANAGEMENT

A. Time interval. One of the first and primary considerations in a discussion of the treatment of abdominal wounds is the time element involved from injury to time of operation. Everyone is familiar with the surgical dicta laying down the relationship of increased mortality with delayed time intervals before operation in acute traumatic intra-abdominal conditions. We feel that in view of our experience, although the importance of the time element cannot be refuted, some revision of thought in regard to this matter must be considered. The average time from injury to operation in this hospital was roughly 18 hours, approximately three times the usually accepted safe interval prior to operation. We say "roughly" because in some cases it was impossible to find out the exact time of injury, but it was known to be within 24 hours. In computing this average, however, these cases were calculated as an interval of 24 hours. The extremes of the series were 1 hour for the earliest and 56 hours for the latest.

B. Condition of patient on admission. The condition of the patient on admission was the index to surgical treatment not only of those with abdominal wounds, but of all wounded admitted to this hospital. Under this index was included the length of time elapsed since the injury if obtainable, degree of shock, presence or absence of continued internal hemorrhage, magnitude and condition of wound or wounds, and general mental and physical condition of the patient. Of these, in the majority of cases we feel that accurate determination of the degree of blood loss and shock and ade-

quate treatment of these has a more important bearing on the outcome of the case than any other factor in treatment. It must also be remembered that many of these patients had been exposed to enemy action continuously for long periods of time, sometimes without adequate water, food, or rest. Thus their general mental and physical condition was definitely subnormal. Their youth and general good physical condition as a result of military training were factors of definite advantage to both the patient and the surgeon.

SURGICAL MANAGEMENT

Preoperative management. Before operation, all patients with abdominal wounds were treated in the shock wards. Patients to be treated conservatively without surgery or on whom surgery had been done elsewhere, were also admitted to the shock wards and received their initial treatment there.

The most important factor in preoperative management was the accurate estimation of the degree of shock, amount of blood loss, and presence of continued bleeding. All patients with abdominal wounds were suffering from some degree of shock, from slight to irreversible, and needed prompt and adequate treatment for the same. In most of the patients with abdominal wounds, shock was the result of the trauma of injury and associated blood loss. Perusal of the literature often gives one the impression that plasma affords complete replacement therapy. The degree of blood loss does not seem to have been generally appreciated. Only by its replacement with blood can these patients be properly prepared. Repeated instances have occurred in which large quantities, 1000 to 2000 cubic centimeters of plasma, have been given to patients while awaiting procurement of blood, and effective response to treatment was not obtained until after the blood transfusion had been given at times in amounts of 1000 cubic centimeters or more. Furthermore, those patients receiving blood seemed to withstand the necessary reparative surgery much better than those receiving only plasma before, during, and after operation. Hamilton and Duncan state that hemorrhage more often than peritonitis was the cause of death in their series of cases.

The first consideration in preoperative treatment was the arrest of any visible hemorrhage, often the result of an associated wound. To accomplish this tourniquets, pressure dressings, and occasionally hemostats were applied promptly. The administration of plasma intravenously was then begun immediately while at the same time a specimen of blood for cross-matching was obtained. The wounded soldier's blood type was indicated on his identification tag. Only in the most dire emergencies, was blood from a universal donor given without cross-matching. In 374 transfusions, 5 reactions were noted and none of these was fatal as they were of a pyrogenic rather than a hemolytic type.

Until the increasing number of transfusions required made it impossible, the blood was obtained from the personnel of this hospital. Then a living blood bank composed of service troops was established. A proportionate number of each of the four types was brought to this hospital daily, and they were available 24 hours a day; as soon as they had been used as donors, they were returned to their respective commands. In most cases, it was possible to have a transfusion of whole blood set up and blood running in the patient's vein in 45 to 60 minutes; in dire emergencies, without cross matching, less than 30 minutes. Following the southern Tunisian campaign a kerosene burning refrigerator was obtained and a blood bank of refrigerated blood was maintained. This bank made possible the constant availability of blood of known type for immediate cross matching when needed. The total elapsed time between admission of the patient and his reception of the transfusion was thereby markedly reduced, usually to 30 minutes, the time necessary for the cross match itself.

The amount of plasma and blood used varied, some patients needing only 250 cubic centimeters of plasma to prepare them for operation. In others, as high as 2500 cubic centimeters of plasma and the same amount of blood over a period of 24 to 36 hours would be given. In explanation of this statement, those large amounts would be given before operation, during the surgical procedure, and in the immediate postoperative period. We have never experienced the untoward toxic

reactions from large volume transfusions with citrated blood in patients with massive hemorrhage, as has been suggested by Ivy and associates. Contrary to the belief of some writers in current literature that plasma alone is satisfactory in the treatment of shock associated with hemorrhage, we believe from our experience that nothing takes the place of whole blood. This opinion is based not only on this small series of abdominal cases but also upon observation of the large number of other casualties of a major nature admitted to this hospital. Enough blood and plasma must be given to stabilize the circulation by complete restoration of the circulating blood volume before surgery is attempted. Each case is an individual problem and no dogmatic rule can be laid down as to the amount to be given. During the period when the patient was getting plasma, blood, or both, an attempt was made to keep the patient warm and quiet so he could get as much rest as possible. If morphine was indicated, it was given. However, it is surprising how many of these men when put to bed, warmed with hot water bottles and blankets, dropped off to sleep without any sedation. If indicated, oxygen was administered with a BLB[1] mask at 4 to 6 liters per minute. Occasionally 5 per cent glucose in saline was given intravenously in an effort to convert what appeared to be a marked imbalance of the electrolytes as the result of dehydration. If this treatment outlined did not stabilize the patient's circulation, no attempt was made to perform any surgery unless it was felt the patient had active internal bleeding. In that case, with both blood and plasma running in two different veins, surgery would be undertaken with the idea primarily of stopping the hemorrhage. Otherwise we felt that the patient was in irreversible shock and attempts at surgery would be futile. In most cases of this type, the magnitude of the wounds precluded any possibility of life. However, the maximum attempt was always made to improve the patient's condition to the point at which surgery was justifiable without absolutely assured mortality. It is for the reasons listed that we say the condition of the patient is more important than the time element in the majority of the wounded in determining the time of operation and successful outcome of the case.

[1] Boothby, Lovelace, and Bulbulian.

Operative management. It would be impossible to describe the surgery involved in each individual case. However, we believe that certain features in technique and some of our observations may be of value to those soon to be exposed for the first time to this type of surgery.

A tabulation of viscera involved and the type of wound is shown in Table I. The table shows that in most cases several intra-abdominal viscera have been injured. The incidence of associated extra-abdominal injury and the region involved, is noted in Table II. In both tables, statistics are given for patients operated on after admission as well as those operated prior to admission.

Persual of the tables will also further indicate that not only are 2, 3, or 4 different organs frequently involved in the injury but, when the small bowel is involved, multiple perforations occur about ten times as often as single parforations. In some cases as many as sixteen perforations of the small bowel were encountered. Involvement of diaphragm, the liver or spleen with perforation of small or large bowel, or both, was also not uncommon.

Although the majority of patients came to operation in relatively good condition, some were in precarious condition and did not respond to intensive measures to stabilize the circulation and in them it was our opinion that active internal bleeding was present. Although the speed of an operating surgeon is not usually considered the essential criterion in any operative procedure, in these cases it was very important. For that reason, it has been our policy to do the simplest and most easily performed procedures compatible with saving the patient's life, even though this might necessitate further surgery at some future date. Even following this policy, many of the operative procedures were exceedingly long because of the magnitude of the injury. It has been most revealing to see the tremendous amount of injury and associated operative repair a previously healthy young adult will tolerate and survive. How a missile can

TABLE I.—TABULATION OF VISCERA INVOLVED AND TYPE OF WOUND

Viscera involved	Type of wound	Patients operated upon after admission			Patients operated upon prior to admission		
		No.	No.	No.	No.	No.	No.
Diaphragm				3			2
	Perforation		1			0	
	Laceration		2			2	
Stomach				7			3
	Perforation		4			0	
	Laceration		3			3	
Small intestine				28			9
	Single perforation		2			0	
Duodenum		1			0		
Jejunum		1			0		
Ileum		0			0		
	Multiple perforations		20			9	
Duodenum		10			0		
Jejunum		12			4		
Ileum		8			5		
	Lacerations		6			0	
Duodenum		1			0		
Jejunum		3			0		
Ileum		2			0		
Colon				17			5
	Single perforation		5			3	
Ascending		1			1		
Transverse		1			1		
Descending		3			1		
	Multiple perforations		6			1	
Ascending		0			1		
Transverse		3			0		
Descending		3			0		
	Lacerations		6			0	
Ascending		0			0		
Transverse		1			0		
Descending		5			0		
Rectum				7			0
Intraperitoneal	Perforation		1			0	
	Laceration		2			0	
Extraperitoneal	Perforation		1			0	
	Laceration		3			0	

TABLE I.—TABULATION OF VISCERA INVOLVED AND TYPE OF WOUND—Continued

Viscera involved	Type of wound	Patients operated upon after admission			Patients operated upon prior to admission		
		No.	No.	No.	No.	No.	No.
Mesentery				7			0
	Perforation		1			0	
	Laceration		3			0	
	Hematoma		3			0	
Liver				10			3
	Perforation		4			0	
	Laceration		6			3	
Spleen				11			2
	Perforation		4			0	
	Laceration		7			2	
Biliary tract				3			0
Gall bladder	Laceration		2			0	
Common Duct			0			0	
Hepatic Duct	Small perforation		1			0	
Pancreas	Small crease			1			0
Genitourinary				13			1
Kidney			0			0	
Ureter			0			0	
Bladder			13			1	
Intraperitoneal	Perforation	2			0		
	Laceration	3			0		
Extraperitoneal including urethra	Perforation	1			0		
	Laceration	7			1		
Retroperitoneal space	Hematoma			5			2
Total injuries to viscera				112			27

SUMMARY

	Patients operated upon after admission	Patients operated upon prior to admission
Patients with penetrating abdominal wounds in whom it was felt exploration was mandatory but no intra-abdominal injury was found	8	0
Total number of cases in whom there was injury of intra-abdominal viscera	59	16
Average number of viscera involved per case (112 in 67)	1.68	1.69
Mortality rate	11.94	31.25

pass entirely through the abdominal cavity without injury to any intra-abdominal structure is another matter of interest. This fact explains the exploratory procedures done because of abdominal wounds requiring investigation, in whom no intra-abdominal injury was found. (Table I).

The first consideration in operative management is elementary in surgery—adequate exposure. The previous notation by fluoroscopy of the location of foreign bodies when lined up with the point of entrance gave some idea of the region of the abdomen traversed by the missile or missiles, and the incision was planned accordingly. We have usually used a long rectus or paramedian incision, depending upon the side we felt the intra-abdominal injury pre-dominated. If uncertain, a midline incision going either to right or left of umbilicus may be enlarged to cope with any situation that may be encountered. Sometimes because of damage to abdominal parietes, the site of incision is precluded. When the abdomen was opened, our first concern has been the control of any active bleeding if present, usually from the spleen, liver, or mesentery. In cases with a great deal of intraabdominal bleeding, a suction apparatus is invaluable. The amount of bleeding from apparently trivial injuries of the mesentery or a few perforations of the small intestine, can be tremendous and out of all proportion to the injury that is found.

After any active bleeding is controlled, the next step has been a systematic examination of the abdominal viscera. We have examined colon first, closing temporarily any perforations by Allis clamps to avoid any further contamination of the abdomen if perforation was present. One must be careful not to overlook extraperitoneal injuries of the large bowel. Examination of small bowel, beginning at the ligament of Treitz or the cecum was done next, care being taken to discover any possible injury of the mesentery. Other intra-obdiminal viscera were then systematically examined.

In most severe liver injuries, suture will be impossible. Muscle grafts and a pack have controlled hemorrhage from severe liver injuries very well in our experience. Suture

TABLE II.—INCIDENCE OF ASSOCIATED EXTRA-ABDOMINAL INJURY AND REGION INVOLVED

Region involved	Patients operated upon after admission	Patients operated upon prior to admission
Head	2	0
Chest	10	0
Back	5	0
Upper extremity	7	0
Lower extremity	21	2
Total incidence associated injury	45	2
Total cases	67	16
Percent of cases with associated injury	67.31	12.50

may be done in injuries of lesser degree. For this, we have used heavy chromic catgut. These cases were all drained (except one early case) using either the end of the liver pack or separately by Penrose drains. Drainage was done to establish a tract for drainage of blood, bile, or any dead liver tissue that might sequestrate at a later date. It may be and is usually advisable to give small dose of sodium pentothal when the pack is later removed. We have found one case of secondary complete mechanical intestinal obstruction the result, we felt, of reaction to a liver pack that had been left in too long. For that reason we believe that we should start to remove the drains in 3 to 5 days.

If the injury to the spleen was of a minor nature, as a crease on the surface or a small laceration in a border with no bleeding present, nothing was done. If the splenic wound was of a major nature, splenectomy was done and no attempt made to pack or suture the organ.

Minor perforating and lacerating wounds of the stomach were closed by two layers of inverting sutures in most instances without trimming away any everting gastric mucosa. In major lacerating injuries, some revision of the wound or partial gastric resection was sometimes necessary to effect a tight and anatomical closure. This was also done with two layers of inverting sutures. Connell, Lembert, or Cushing sutures may be used as desired. Both catgut and silk were used, silk on the outer layers preferably because no

catgut sutures with atraumatic needles were available and it was our opinion that less trauma was produced by the use of silk.

The small intestine was the most commonly, and usually the most extensively, involved of the intra-abdominal viscera. Injury ranged from a single perforation to almost complete mutilation of a segment of gut. The repair of injuries to small bowel had an important bearing on the length of the operative procedure. In some cases in which patients were in very poor condition with a tremendous amount of damage closure of minor perforations and lacerations was done with one row of suture inverting serosa to serosa. Although this is not recommended as a routine procedure, in dire emergencies it has been used successfully. Routine closure was by two layers of inverting suture, in the transverse axis of bowel; the everted mucosa was not trimmed away. Resection was done when the blood supply was damaged either by injury to the mesentery or by separation of the mesentery for any distance greater than 2 inches; when there was a complete mutilation of a segment of bowel; or when multiple perforations were so placed that their repair would constrict the lumen of that segment of bowel. Both end-to-end and side-to-side anastomoses were used in resections and in repair of transections of intestine. It is not within the realm of this paper to discuss the merits of these two types of anastomoses. Both have given satisfactory results in our hands, but an end-to-end anastomosis was used more frequently because it could be completed in a shorter interval of time.

Most lesions of the colon were exteriorized. This was done for two reasons: first, it was the simplest and least time consuming thing to do in most cases, especially when injury to other viscera necessitated a long operative procedure, and, second, these patients had had no preparation for colon surgery and unless the lesion was very minimal and the bowel empty it was a safer procedure than primary suture or resection and anastomosis. If resection had to be done, a Rankin obstructive type or a modified Mikulicz procedure was used. Occasionally a colon perforation or laceration was sutured primarily. Suture would also be done if there was already a colostomy for an associated injury proximal to that particular lesion. Colostomy was done for extraperitoneal perforation of the rectum.

Rents or lacerations of the diaphragm were closed routinely with interrupted mattress silk sutures, closure being in the direction of the fibers with overlapping of the edges.

We have deemed it inadvisable to try to control retroperitoneal hemorrhage as in our experience it has always been self limited. Neither have we deemed it advisable to explore the retroperitoneal space for a known foreign body in the presence of a retroperitoneal hematoma. Our results would seem to indicate that our surmise has been correct.

Intraperitoneal lesions of the bladder were repaired with two layers of inverting sutures. If there was a perforation or a small laceration, an indwelling urethral catheter was used; if a large laceration, a suprapubic cystostomy was done. A suprapubic cystostomy was also done for extraperitoneal lesions of the bladder or injuries of the urethra in which it was completely severed or impossible to pass a urethral catheter.

Sulfanilamide powder (10 to 15 grams) was placed in the peritoneal cavity in all exploratory celiotomies. Drainage was employed only in wounds of the biliary tract, urinary tract, and colon. All other incisions were closed tightly. In some cases of gross contamination from injuries of the colon, only the peritoneum was closed initially, and secondary closure of the remaining layers was done at a later date when the wound was clean.

The anesthesia of choice in most cases was nitrous oxide—either by closed absorption technique or drop ether. Not infrequently, an intratracheal tube was used. Rarely, in patients in exceptionally good condition, spinal anesthesia was employed. The agents most commonly used were 1.5 cubic centimeters of nupercaine, 1:200 dilution and 100 to 150 milligrams of procaine.

In most cases the administration of plasma or blood has been continued throughout the surgical procedure.

Postoperative management. Postoperatively, most patients with abdominal wounds were

returned to the shock ward and further treatment was given to prevent, if possible, any postoperative shock. Oxygen, constant gastric suction, and intravenous sodium sulfathiazole or sodium sulfadiazine were used routinely, 5 grams being given initially and followed by 2.5 grams every 6 to 8 hours. Fluid balance was closely checked, 1000 cubic centimeters of normal saline, 2000 cubic centimeters of 5 per cent glucose in distilled water and 500 cubic centimeters of plasma being given daily to meet the basic electrolytic and protein requirements. Additional 5 per cent glucose in normal saline was given to equal the amount of drainage by the gastric suction. In some cases this would bring the total fluid requirement to 10 to 12 liters a day. Only one patient developed an edema. A urinary output of at least 1000 cubic centimeters in 24 hours was maintained. In absence of adequate laboratory facilities for accurate studies in blood chemistry, we felt this rule of thumb worked very well. Adequate amounts of intravenous vitamins B and C were administered with the parenteral fluids each day. Usually in 4 to 5 days sufficient peristalsis associated with the passage of flatus was present to permit the removal of the nasal tube. Patients then began the usual liquid diet for surgical patients of this type. Blood transfusions were given as indicated. Careful check was kept on all blood counts and urine to detect at once any deleterious effect from the intravenous sulfonamides. In 7 to 10 days most patients were transportable, in good enough condition so that, except in a very few instances, they were again evacuated to the rear from the large evacuation hospital to which we had sent them. There were no deaths during or as the result of transportation in any of this group treated and held until we felt they were fully transportable, on the way to or at any evacuation hospital. No deaths were reported during the latter phase of evacuation.

ANALYSIS OF RESULTS

In this series of 67 patients operated on and cared for in this hospital until fully transportable, there were 8 deaths, a mortality rate of 11.94 per cent.

A brief résumé of these fatal cases follows:

CASE 10. An invasion casualty who had extensive wounds of the urinary bladder and posterior urethra, died 7 weeks after operation of a series of complications resulting from a small, low sigmoid perforation. Additional unfortunate circumstances influencing the patient's course cannot be given in detail.

CASE 21. Patient with a left-sided thoracoabdominal wound had had the external chest wound superficially sutured prior to admission. Due to severe laceration of the stomach and diaphragm, the patient had developed an internal sucking wound of the chest. (This case is being reported in more detail by one of us [JMS] with another member of the hospital staff in a series of 107 thoracic cases.) Operative closure of the diaphragm allowed development of a tension pneumothorax which blew out the external wound at the close of the abdominal operation, and the patient died from the shock of recurrent severe changes in the intrathoracic pressures, superimposed upon an already severe injury.

CASE 25. Patient had multiple extremity wounds and complete destruction of the blood supply to the small bowel at the root of the mesentery, with gangrene; operative fatality.

CASE 40. Splenectomy was done for a shattered bleeding spleen, anastomosis following resection of destroyed portion of jejunum and Rankin obstructive resection of badly damaged transverse colon. Death occurred 16 hours after operation despite a transfusion of 2000 cubic centimeters of whole blood.

CASE 47. Severe blast lacerations (2) of the stomach and multiple shrapnel perforations of the small bowel. All repaired but patient died 12 hours after operation in shock despite transfusion of 1500 cubic centimeters of whole blood.

CASE 49. Severe intra-abdominal hemorrhage from splenic vein which had been severed by a shell fragment behind the junction of the middle and distal third of the pancreas with death before hemorrhage could be controlled.

CASE 51. Débridement of multiple, severe shell fragment wounds of all extremities, packing of severe lacerations of liver, and repair of stomach laceration. Patient died 24 hours after operation of sudden, severe, secondary shock.

CASE 66. Multiple, severe shell fragment wounds of left side of the body including compound fractures of the left humerus and left femur, multiple small bowel perforations (ileum) and lacerated transverse colon. Patient died suddenly following convulsive seizure during anesthesia.

IMMEDIATE POSTOPERATIVE COMPLICATIONS

The incidence of postoperative complications in the same group was remarkably low considering the magnitude of most of the wounds and surgical procedures necessary for their repair.

There were 3 patients in whom pulmonary complications were present, 2 had a partial atelectasis, 1 had a bronchopneumonia. Whether routine use of sulfonamides had any influence on this low incidence of pulmonary complications is only conjecture. An attempt was always made to see that the air passages were entirely clear after surgery, and this undoubtedly had some beneficial effect. Except for the first case previously discussed under fatalities, there were no cases of postoperative ileus or of evisceration. It is appreciated that all were treated after operation with constant gastric suction. However, the early return of peristalsis and successful discontinuance of the gastric suction in all cases but one on the first attempt would seem to indicate that protein intake had been adequate. A hypoproteinemia, initiated by restricted diet during prolonged combat, can develop with the Levine tube in place and only manifest itself by ileus when attempts are made to clamp off or remove the tube. Although it was not possible to make plasma protein determinations, it was felt that many of these patients could have had lower plasma protein levels than normal because of having been on restricted field rations for long periods of time. The same may be predicated for vitamin levels, especially ascorbic acid. The fact that there was prompt wound healing with no wound dehiscence would also seem to indicate that adequate plasma protein and ascorbic acid levels had been maintained.

There were no instances of parotitis or genitourinary complications. Again one might think of the rôle of sulfonamides used, and again this is only conjecture.

SURGICAL MANAGEMENT AND ANALYSIS OF CASES OPERATED ON PRIOR TO ADMISSION

A group of patients was received and treated in this hospital after some surgical procedure had been done by the personnel of a clearing station or by an auxiliary surgical team attached to the clearing station. These patients were received at varying intervals after surgery had been done, some still under anesthesia, some 4 days after operation. The average time from surgery until they were transported was about 48 hours. There were 16 patients in the group with 5 deaths, a mortality rate of patients treated in this hospital and held until they were fully transportable. The incidence of complications was also noted to be higher. It might be said that these patients were in worse condition necessitating operation at a clearing station. There were, however, none of these in whom the magnitude of the wounds exceeded the general severity of abdominal wounds treated primarily in this hospital (Tables I and II). It would seem, all other things being equal, that this would show conclusively that postoperative celiotomies do not tolerate early transportation. It seems, therefore, that it would be better to transport these cases far enough from the front before definitive treatment, so that once treatment has been initiated, it can be completed and the patients cared for after operation until they are fully transportable. The same postoperative measures we discussed as employed on patients operated upon in this hospital were used on this group of patients previously operated upon. Complications were treated as indicated; one patient developed a complete mechanical obstruction which necessitated reoperation. A brief analysis of the mortalities in this group is presented:

1. Patient had a wound of right lower abdomen from a rifle bullet. Resection of terminal ileum and exteriorization of cecum were done. He was received in less than 48 hours in very serious shock, but he responded to plasma and blood transfusions. On 7th postoperative day he developed gastric dilatation and again presented a picture of shock. A Levine tube was reinserted. An anuria developed and patient died on 10th postoperative day, despite all measures to relieve it.

2. Patient had a wound of the abdomen and celiotomy had been done 36 hours previous to admission. No record of type of operative procedure was received. He arrived in shock and with beginning peritonitis. Supportive treatment was given. Thirteen hours after admission he had a profuse hemorrhage from the wound which soaked bed and he expired.

4. Patient had a combined thoracoabdominal wound, left, which was caused by shell fragments. Repair had been done of laceration base of left lung, of lacerations of diaphragm, stomach, small intestine, and transverse colon, and the spleen had been removed. He was admitted 36 hours after operation in shock. In spite of blood transfusions and plasma in adequate amounts, patient expired in 17 hours.

TABLE III.—CONSERVATIVE SURGICAL MANAGEMENT

Causative missile	Region of the wound	No.	Comments
Shell fragment	Right lower thorax	3	It was our opinion that each of these patients had small combined thoracoabdominal wounds with very small wounds of the liver with slight intra-abdominal hemorrhage. Their condition was good and it seemed that nothing would be gained by operation.*
Shell fragment	Right back—just behind liver	1	It was believed that there was a small wound of the liver with a retro-peritoneal hematoma.
Shell fragment	Right upper abdomen	1	Same as 1.
Shell fragment	Left lower abdomen	1	36 hours old—colostomy created at time of injury and functioning. Did very well until 72 hours after admission when patient suddenly died. Death—classical picture of pulmonary embolus.
Bomb fragment	Left flank and back	1	Fracture—spinal column with cord injury. Colostomy and nephrostomy or ureterostomy created by missile. Nothing to be gained by surgery.
Shell fragment	Right kidney area	1	Rigid abdomen, peristalsis active. It was believed from location of wound that there was a retroperitoneal hematoma without intra-abdominal injury.
Rifle bullet	Left lower chest	1	Thirty-six hours old—good condition. No peritonitis. X-ray showed bullet behind stomach. In view of patient's good condition, it was decided that there was nothing to be gained by removing bullet at this time.

*Turner has stated that, from experience gained in World War I, conservative treatment should be followed when it is believed the liver injury is not serious.

8. Patient had a shell fragment wound of the lower abdomen. Eight inches of the ileum had been resected. He was admitted still under anesthesia and in extreme shock. He died in 36 hours in spite of all supportive measures.

9. Patient had a perforating shell fragment wound of the abdomen. Three perforations of the ileum and three of the cecum were closed. Patient was admitted under anesthesia, pulseless, and with no demonstrable blood pressure. He died in 6 hours in spite of all supportive measures.

CONSERVATIVE SURGICAL MANAGEMENT AND ANALYSIS OF CASES

The third and last group of patients to be considered are those who were treated conservatively without operation. This last group must be divided into two types: patients treated conservatively from choice and those treated in that manner by necessity. In the latter type were those patients who were either already moribund or who did not respond to the measures we used to combat shock and in whom death was inevitable.

In the first type, initial treatment was the same as that received by a patient on whom surgery was contemplated, the primary aim being adequate treatment of shock. After this initial treatment, supportive and therapeutic measures were employed in each individual case as required, usually similar to the management employed in treating patients after an operation. This included adequate intake of protein, glucose, salts, vitamins, and fluids, some form of sulfonamide therapy parenterally if indicated and oxygen or constant gastric suction if needed. This group needed particularly constant vigilance. Upon initial examination with the course of the missile, by examination and x-ray, known to have missed the gastrointestinal and urinary tracts, the greatest determinant of operative or nonoperative management was the progression or regression of the signs of intraperitoneal irritation. This included indications of localization, accentuation or diminution of other signs present, especially the changing activity of peristalsis. The degree of evident peritoneal reaction in proportion to the duration of injury was also given due consideration in determining treatment.

There were 9 patients treated in this manner with 1 death, a mortality rate of 11.11 per cent. This death was from pulmonary embolus and is not considered an error in treatment.

In the second type of patient of this group, those treated without surgery by necessity, there were 6 cases and 6 deaths, a mortality rate of 100 per cent. Two cases of this type are cited as examples.

1. Patient had a shell fragment wound of the upper abdomen, which was 40 hours old on admission and complicated with diffuse peritonitis. A diagnosis of ruptured viscus was made. Surgery was contraindicated and a modified Ochsner regimen was instituted. Patient died in 24 hours.

2. Patient had multiple shell fragment wounds including lacerating wound of the right and middle

lower abdomen with loss of tissue of abdominal parietes; evisceration and multiple perforations of the small intestine were visible; and there were severe penetrating wounds with compound fractures of the left forearm, right arm, left thigh and leg. The patient was in irreversible shock and in spite of 1000 cubic centimeters of whole citrated blood and 750 cubic centimeters of plasma, he died shortly, less than 4 hours after admission. The extent of his injuries precluded any possibility of life and any attempted surgery would only have resulted in a death on the table.

SUMMARY

1. A series of 98 cases of abdominal war wounds with 20 deaths, an overall mortality of 20.41 per cent, is presented.

2. In 67 of the patients who were operated on and treated in this hospital until they were fully transportable, a mortality of 8 or 11.94 per cent is reported.

In 16 patients operated upon previous to admission to this hospital and cared for here until transportable, a mortality of 5 or 31.25 per cent is known. This would seem to indicate that postoperative abdominal cases do not tolerate early transportation.

3. In restoration of circulating blood volume in cases of shock due to trauma of injury and blood loss, plasma alone is not sufficient; citrated whole blood transfusions must be used in a high proportion of cases. The amount of blood loss may be easily underestimated.

4. No toxic reactions from large volume citrated blood transfusions were noted.

5. Involvement of multiple intra-abdominal viscera should be expected in penetrating abdominal war wounds and, at operation, complete and careful exploration should be done to avoid overlooking some remote injury.

6. Associated extra-abdominal injury with the abdominal war wound is the rule rather than the exception.

7. The average time which elapsed between the time of injury and operation was 18 hours.

The relatively low mortality (11.94 per cent) in this group as the result of modern preoperative and postoperative therapeutic measures would seem to warrant some revision of thought regarding the duration of the safe interval of operability from the time of injury to operation. This interval, as has so often been stated, should not exceed 6 hours.

8. The condition of the patient on admission to the hospital is, in our experience, the most important index of the type of treatment which should be carried out.

9. In spite of the evident abdominal wound, conservative rather than operative treatment is sometimes indicated by the duration, location, and severity of the wound and the signs and symptoms present.

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VAGOTOMY IN THE THERAPY OF PEPTIC ULCER

VERNON A. WEINSTEIN, M.D., F.A.C.S., Captain, M.C., A.U.S., RALPH COLP, M.D., F.A.C.S., FRANKLIN HOLLANDER, Ph.D., and EDWARD E. JEMERIN, M D., F.A.C.S., Captain, M.C., A.U.S., New York, New York

RECENT years have seen increasing emphasis placed upon the rôle of psychic factors in peptic ulcer. Whether this rôle is a dominant or a subordinate one is not clear, and its importance may vary in individual cases, but that it is usually present to some extent is widely accepted today. Despite this, the procedure of choice for those cases which do not respond to a medical regimen is subtotal gastrectomy—an extremely radical surgical procedure, associated with a varying percentage of unsatisfactory results. The rationale of this procedure is to diminish or abolish the acid secretion, and to remove, if possible, the ulcer-bearing area. This obviously does not get at the basic etiological mechanism but merely breaks into and interrupts a vicious cycle set up by more remote causes. Surgical procedures, similarly directed toward a single facet of a much broader problem, are used extensively in the treatment of Graves' disease, hypertension, and ulcerative colitis, although in each of these a more rational approach is the ultimate desideratum.

Since the psychic factors in the genesis or perpetuation of peptic ulcer (i.e., those having to do with the psychic phase of gastric secretion and with motility) are mediated through the vagus, it would seem logical to attempt to interrupt these influences by section of the gastric branches of this nerve. A few reports in which this procedure was employed are to be found in the literature, but these deal in great part with the application of vagus section to neurogenic gastric disorders, such as gastric crisis in tabes dorsalis. In 1912, Exner and Schwartzman reported 20 cases in which they had performed subdiaphragmatic anterior vagotomy for gastric crises in tabes (Fig. 1). Ten of their patients were cured, and 2 were improved; there was 1 operative death. Latarjet devised a more extensive operation in an effort to achieve complete division of the vagus supply to the stomach (Fig. 1). The aim of this procedure was "to cut off sensation, diminish the frequency and intensity of the contractions, and probably to diminish acidity." Twenty-five patients were operated upon, and good results were obtained in those suffering from gastric crises without organic disease of the stomach or duodenum. Bircher, Schiassi, and Stierlin, also devised surgical techniques for vagotomy (Fig. 1) and reported good results in the treatment of peptic ulcer. In 1937 Barron and Curtis reported a case of gastric hypertonia in which an anterior vagotomy was done. They observed a marked decrease in the periods of gastric motility, the effect lasting for at least 5 months after operation. Winkelstein and Berg in 1938 advocated an anterior subdiaphragmatic vagotomy plus a subtotal gastrectomy for the surgical treatment of duodenal ulcer accompanied by high gastric acidity. They reported 34 cases of which 26 developed achlorhydria: 16 immediately and 10 later on. Their method of vagotomy is similar to that of Exner or step A of Latarjet's procedure in Figure 1.

With the possible exception of Latarjet, all of the forementioned authors employed partial rather than total vagotomy. This may have been done for any one of several reasons: the belief that partial vagus section would accomplish the objective, or the opinion that total division constituted too difficult a surgical feat, or the fear of possible harmful physiological effects upon the organism of complete vagus section. However, a considerable volume of experimental data has been published on the effect of section of the vagus upon gastric secretion and motility. It may be of value to review briefly some of these findings.

McCrea and his associates (11, 12) reviewed the subject comprehensively up to 1925. Their conclusions were as follows: The motor activity of the stomach is unaffected by unilateral vagotomy, and save for a decrease in the initial emptying time, it is not markedly influenced by double vagotomy. Section of the vagi eliminates the psychic secretion, but an "active gastric juice is still secreted" because of the chemical phases. Hartzel in 1929, following intrathoracic vagotomies on dogs, reported that complete vagotomy induced a decrease in acid secretion, but if the vagotomy were incomplete no such result was

From the Laboratories and the Surgical Service of The Mount Sinai Hospital, New York City.

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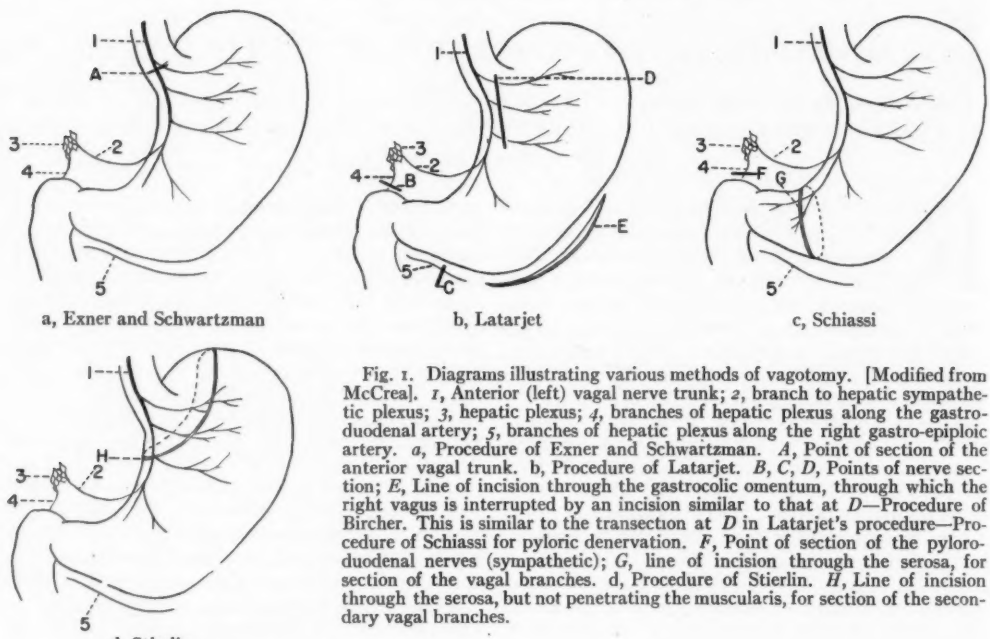

Fig. 1. Diagrams illustrating various methods of vagotomy. [Modified from McCrea]. *1*, Anterior (left) vagal nerve trunk; *2*, branch to hepatic sympathetic plexus; *3*, hepatic plexus; *4*, branches of hepatic plexus along the gastroduodenal artery; *5*, branches of hepatic plexus along the right gastro-epiploic artery. *a*, Procedure of Exner and Schwartzman. *A*, Point of section of the anterior vagal trunk. b, Procedure of Latarjet. *B*, *C*, *D*, Points of nerve section; *E*, Line of incision through the gastrocolic omentum, through which the right vagus is interrupted by an incision similar to that at *D*—Procedure of Bircher. This is similar to the transection at *D* in Latarjet's procedure—Procedure of Schiassi for pyloric denervation. *F*, Point of section of the pyloroduodenal nerves (sympathetic); *G*, line of incision through the serosa, for section of the vagal branches. d, Procedure of Stierlin. *H*, Line of incision through the serosa, but not penetrating the muscularis, for section of the secondary vagal branches.

obtained. Vagus sections done in the abdomen showed no constant decrease in the height of the acid curve but some decrease in its duration. Wilhelmj, McCarthy, and Hill performed a partial gastrectomy and complete vagotomy on 4 dogs. In only 33 per cent of their experiments was there anacidity, but the average acid curve was lower than that with partial gastrectomy alone. Ferguson, in 1936, sectioned both vagi in the cervical regions of 5 monkeys. These animals all died of aspiration pneumonia. Five other monkeys in which subdiaphragmatic vagotomy was performed all survived. Their gastric acid figures were observed to be the same before and after vagotomy. Although there was an immediate retardation of motor function, the only permanent symptom was a decrease in initial emptying time. Ferguson, therefore, expressed grave doubt regarding the value of vagotomy in peptic ulcer therapy.

The present authors (9) studied the behavior of 3 types of gastric pouch in dogs: (a) the Heidenhain pouch, which receives no vagus innervation; (b) the Pavlov pouch, in which only a small percentage of vagus fibers remain intact (8); and (c) a "vagal" pouch (7) in which practically all of the vagus fibers are unsevered. They found that secretory responses to the ingestion of food, as measured by the acidity curve, were essentially the same in all three varieties of pouch. When, however, a stimulus was used which operates through the central nervous system (insulin test[1]), the innervated pouches yielded good secretory responses but the Heidenhain pouches did not respond at all (Fig. 2), thus differentiating such denervated pouches from those which retain some degree of vagal innervation. On the other hand, this same central stimulus failed to differentiate between the partially and the completely innervated pouches (i.e., types b and c). In a like manner, purely psychic stimuli, such as sight, smell, or taste of food, elicited similar responses in

[1]The insulin test, which we have found so useful, both in our animal experiments and in our clinical studies, is based upon the physiological fact that a hypoglycemia acts like a central nervous stimulus (probably acting on the medullary centers) and causing secretory impulses to be transmitted by way of the vagus nerves to the gastric mucosa. The hypoglycemic state is induced by insulin administered intravenously. We have found that, in dogs, a blood sugar level of 55 milligrams per 100 cubic centimeters, or lower, must be reached before brain stem stimulation is obtained; in addition, gastric pouch secretory response depends upon the presence of some vagus nerve connection, even though it be but a fraction of the original supply. In human subjects the insulin test is carried out as follows: after an overnight fast, a Rehfuss tube is passed into the stomach and the fasting contents are aspirated. Fifteen units of regular insulin are injected intravenously. Gastric specimens are withdrawn every 15 minutes for 3 hours, and blood sugar determinations are made every half hour for 1½ hours, in order to be certain of an adequate degree of hypoglycemia. The gastric specimens are titrated with tenth normal NaOH in the usual manner. For further details see Jemerin, Hollander, and Weinstein (9).

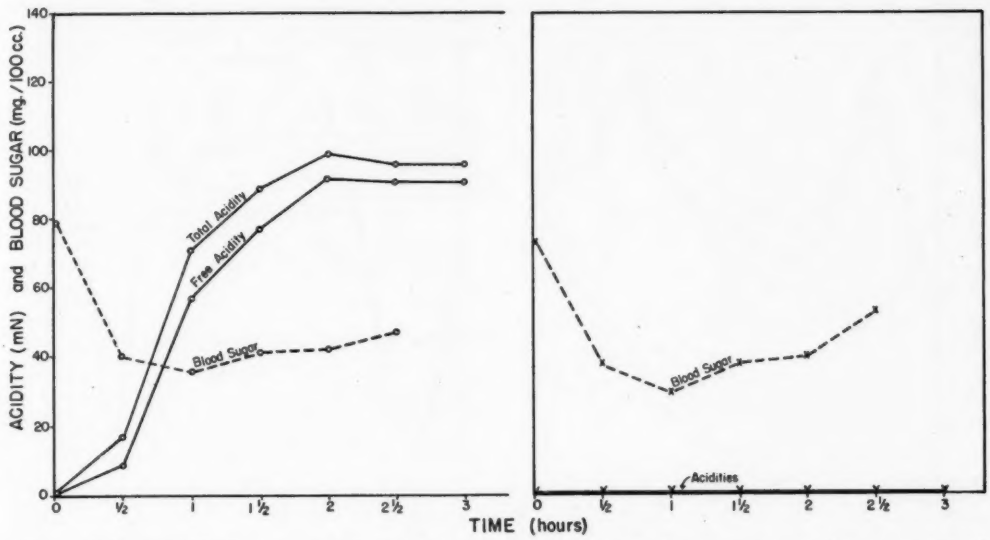

Fig. 2. Acidity and blood sugar curves for insulin tests on a dog (No. 74) with a vagal (Hollander-Jemerin) pouch; before, left, and after conversion to a denervated (Heidenhain) pouch. [Experiments P-30 and P-47].

pouch types b and c despite their marked difference in degree of vagal innervation. These results suggest that partial vagotomy does not eliminate, or even markedly diminish, the gastric secretory response to central nervous stimuli, and that even complete vagotomy may have no significant effect on the total response when ingested food is the stimulus, because of the chemical phases of secretion.

It is our present purpose to report several peptic ulcer cases presenting some unusual problems, in which vagotomy was performed as a therapeutic measure. We desire also to demonstrate the usefulness of the insulin test in determining whether or not a complete vagotomy has actually been accomplished.

CASE REPORTS

We have had the opportunity to study 6 cases upon whom partial vagotomy had been performed. Two had transthoracic (supradiaphragmatic) vagotomies performed for gastrojejunal ulcer after subtotal gastrectomy. In a third case an anterior subdiaphragmatic vagotomy, a Stierlin circumcision vagotomy, and a jejunostomy were done for gastrojejunal ulceration following subtotal gastrectomy. In the fourth case subtotal gastrectomy plus anterior subdiaphragmatic vagotomy was performed for duodenal ulcer. Anterior subdiaphragmatic vagotomy alone was performed for functional gastric complaints in the fifth case, and subdiaphragmatic vagotomy was added to gastroenterostomy for duodenal ulcer in the sixth case. In the first 2 cases the intent was to perform complete gastric vagotomy but later investigation proved that complete nerve severance had not been effected.

CASE 1. K. W. (M.S.H. No. 481734, O.P.D. No. 38–2995). First admission, February 16, 1938. A 34-year old male was admitted to the hospital with a 2 year history of epigastric pain, pyrosis, vomiting, hematemesis, and anorexia. Physical examination revealed a thin, young adult. The heart and lungs were normal. Abdominal examination revealed epigastric tenderness. The stools were positive for occult blood. A Rehfuss test meal revealed fasting contents with a total acidity of 82, free acidity of 70. The total acid value for the first hour was 54, free acid 38; for the second hour the total acid was 94, the free 82; for the third hour, the total acid was 85, the free 70. Roentgenography revealed a deformity of the duodenal bulb suggestive of ulcer. Considerable improvement followed an appropriate dietary regimen, and the patient was discharged to the out-patient department.

Second admission, March 17, 1938. Persistent severe pain recurred immediately after discharge from the hospital. A repeat gastrointestinal x-ray series, Rehfuss test meal, and stool examination gave findings similar to those of the first admission. Inasmuch as medical treatment for 2 weeks in the hospital gave no symptomatic relief, surgery was advised. Subtotal gastrectomy with terminolateral gastrojejunostomy, the duodenal ulcer being left *in situ*, was performed. The postoperative course was smooth and uncomplicated.

Third admission, June 13, 1938. Pain recurred 1 month after discharge and gastrointestinal x-ray revealed a gastro-

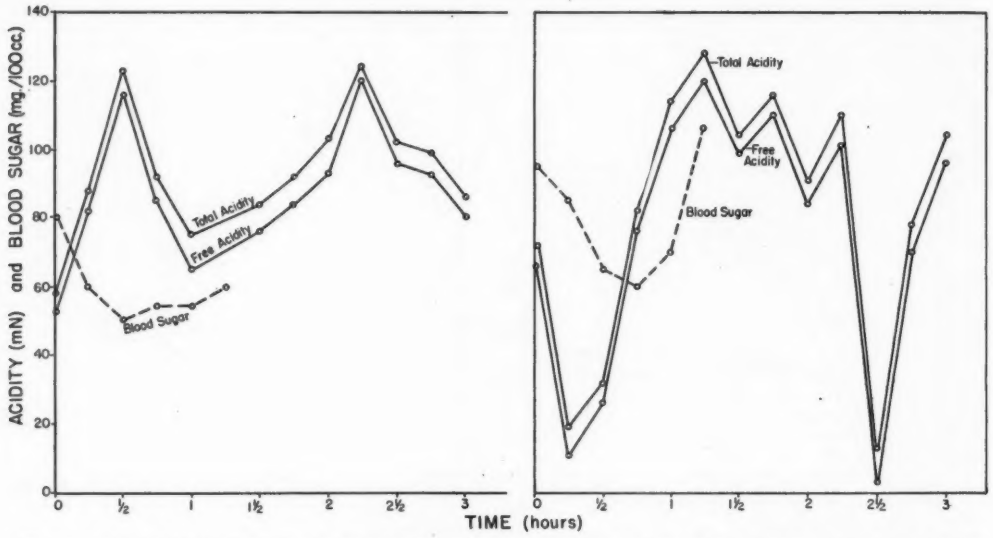

Fig. 3. Acidity and blood sugar curves for insulin test before, at left, and after, at right, supradiaphragmatic vagotomy for peptic ulcer. [Patient: K.W.–M.S.H. No. 481734].

jejunal ulcer. The hemoglobin was 75 per cent; the white blood cell count 10,500 with a normal differential. A Rehfuss test meal revealed total acidity up to 85, free to 65. Milk drip therapy was instituted. The patient improved and was discharged. In follow-up x-ray examination on October 28, 1938, jejunal ulceration was no longer visible.

Fourth admission March 9, 1939. Severe epigastric pain recurred 3 weeks prior to this admission. Gastrointestinal series and gastroscopy both revealed the presence of jejunal ulceration. Some relief was obtained with medical therapy and the patient was discharged.

Fifth admission, November 18, 1939. Readmission was necessitated by the recurrence of severe persistent epigastric pain. It was felt that the patient presented an unusually severe ulcer diathesis and that some alternative to the inadequate medical therapy was required. It was decided to attempt the elimination of central nervous system influences by complete vagotomy, and accordingly a transpleural supradiaphragmatic vagotomy was performed under avertin ethylene anesthesia. A portion of the 8th left rib was resected, and the 6th and 7th were divided near their angles. The pleura was opened and the esophagus was exposed. A large left vagus trunk and a smaller right vagus nerve were divided. The postoperative course was complicated by a large pleural effusion from which the patient recovered. During the hospital stay, epigastric pain was absent, but it recurred on the day of discharge.

Test meals—5th admission	Maximum acidity (free/total)	
	Before operation	After operation
Alcohol	94/98	102/108
Insulin (see Fig. 3)	120/124	108/114
Insulin	—	120/126
Night secretion	84/90	54/58

Sixth admission, October 30, 1940. The patient was treated for an empyema at the site of the thoracic operation by incision and drainage, but there were no gastrointestinal complaints.

Seventh admission, November 13, 1941. Ten months before this admission there had been an episode of melena, and severe epigastric pain recurred 2 months before. A gastrointestinal series again revealed the presence of a jejunal ulcer and an insulin test meal showed a total acid response up to 132 with free acid of 128. The pain was so severe that the patient was willing to submit to another operation. Surgical exploration revealed a jejunal ulcer. The duodenum, which at the time of the first operation had been hard and indurated, was now found to be soft and free of all evidence of an inflammatory process. A portion of the jejunum and an additional portion of the stomach (about 1 inch) were resected, the line of gastric resection being brought juxtaesophageal. An antecolic terminolateral gastrojejunostomy and jejunojejunostomy were then performed. The postoperative course was relatively smooth. Although its values were lower, a postoperative insulin test still revealed an acid response, with maximum total and free acidities of 56 and 50 respectively.

This case is of extreme interest from two standpoints. First, although it was believed that complete gastric vagotomy had been performed, the postoperative response to insulin indicated that this was not the case. Anatomic evidence regarding the validity of the insulin test in this respect is given below (see Case 2, Fig. 4). Technically, therefore, it appears extremely difficult to produce a complete vagotomy, even with the unusually good exposure afforded by a trans-pleural approach. Second, partial vagotomy seems in-

effective in reducing the gastric secretory response to alcohol or to insulin, and the procedure had very little therapeutic effect.

CASE 2. L. U. (M.S.H. No. 448647). First admission, February 25, 1937. This patient was a 38 year old male who had had a subtotal gastrectomy for duodenal ulcer 12 years before. For the past 2 years he had been having epigastric pain and melena. The patient was quite thin, but otherwise physical examination was negative. A gastrointestinal series revealed a gastrojejunal ulcer. He improved under medical therapy.

Second admission, March 4, 1939. Readmitted for ulcer pain and renal calculi. Treated medically with improvement.

Third admission, June 29, 1939. Left nephrectomy for calculus pyonephrosis.

Fourth admission, November 13, 1939. Patient complained of intractible epigastric pain. Physical examination revealed marked emaciation. Epigastric tenderness was present but the examination was otherwise essentially negative. The hemoglobin was 70 per cent. The urine was normal. The blood urea was 17 milligrams per cent. X-ray examination revealed a small gastric pouch and a jejunal ulcer.

Test meals—before operation	Maximum acidity (free/total)
Alcohol	65/70
Insulin	42/48
Night	76/82

Since only a very small portion of the stomach remained, additional resection would necessitate a total gastrectomy with its attendant high mortality. On the other hand a bilateral vagotomy might materially reduce the persistent acid and thus bring the desired therapeutic effect. Accordingly, a (presumably) complete vagotomy was performed through the transpleural supradiaphragmatic route, under avertin-ethylene anesthesia. The postoperative course was complicated by the development of a left hemopneumothorax and a right lower lobe bronchopneumonia. The patient then improved gradually until the 14th day after operation. Just prior to this date roentgenography showed resolution of the right lower lobe pneumonia and a small residual loculation of air in the left chest. On the 14th day, however, the patient suddenly became extremely cyanotic and death ensued rapidly. Postmortem examination revealed a massive hemorrhage into the right adrenal and an atrophic left adrenal (previous nephrectomy). The other findings were a small encapsulated empyema, a jejunal ulcer, and a right renal calculus. The cause of death was hemorrhage into the right adrenal. Dissection of the esophageal and gastric vagi demonstrated that several intact branches to the stomach still remained (see Fig. 4), despite the surgeon's belief that all the vagus branches had been divided. It was estimated that 60 to 80 per cent of the vagal nerve fibers had been interrupted leaving sufficient to mediate a significant degree of gastric acidity, according to our experimental work previously reported.

A careful and determined effort was made to sever all the vagus fibers descending to the stomach, through a transpleural supradiaphragmatic exposure of the lower esophagus. The technical difficulty of achieving this objective is indicated by the postmortem dissection, at which 20 to 40 per cent of the fibers were found to be intact. The same situation probably obtained in Case 1 in which physiological evidence of some vagal integrity was afforded by the response to insulin hypoglycemia.

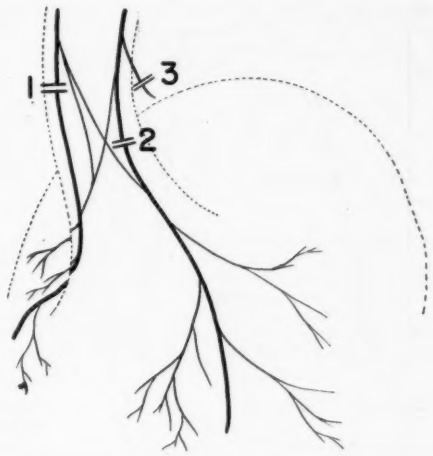

Fig. 4. Diagrammatic representation of the esophageal and gastric vagi following attempted complete vagotomy for peptic ulcer, as revealed by postmortem dissection. [Patient: L.U.–M.S.H. No. 448647]. Branches cut (about 60–80 per cent of the total): *1*, Main posterior division of the right vagus; *2*, main anterior division of the left vagus; *3*, branch of the left vagus to the diaphragm.

CASE 3. L. R. (M.S.H. No. 464135, O.P.D. No. 39–3615). First admission, February 10, 1939. This patient was a 43 year old male, with a proved bleeding duodenal ulcer which had been treated medically for several years. After several weeks of conservative therapy, a subtotal gastrectomy was performed. The preoperative Rehfuss test meal showed maximum free and total acidities of 95 and 110 units respectively at 2¾ hours.

Second admission, August 14, 1940. There had been no complaints referable to the stomach for 14 months, at which time persistent epigastric pain recurred. Gastrointestinal series revealed a jejunal ulcer. Under medical therapy he improved and was discharged.

Third admission, September 11, 1940. Patient was readmitted for severe pain which had recurred several days after leaving the hospital. At this time the stools were positive for occult blood. He again improved on a medical regimen and was discharged.

Fourth admission, October 21, 1940. Readmitted again for recurrence of pain. Surgery was felt to be indicated and accordingly the patient was explored on October 31, 1940. A small remnant of stomach with a gastrojejunal ulcer was evident. The smallness of the gastric segment precluded further resection. Therefore, an anterior vagotomy together with a Stierlin procedure was performed, to insure complete division of the anterior vagus supply. A specimen removed showed nerve tissue without pathological change. A complementary Witzel jejunostomy for alimentation was added. The postoperative course was complicated by the development of a bronchopneumonia from which the patient eventually recovered. Jejunal alimentation was often accompanied by a sensation of burning near

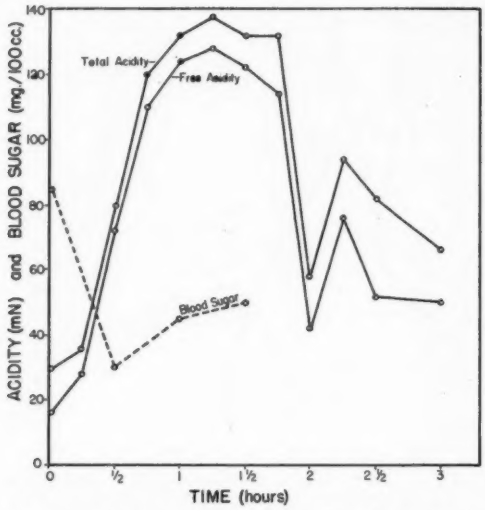

Fig. 5. Acidity and blood sugar curves for insulin test after (partial) anterior vagotomy plus a Stierlin circumcision vagotomy on the anterior surface for peptic ulcer [Patient: L.R.–M.S.H. No. 464135].

the jejunostomy tube. A postoperative insulin test revealed a high acid response (Fig. 5) despite the apparently complete anterior vagus section which had been done. One year later there was a recurrence of epigastric pain (December 20, 1941) for which the patient was treated medically in the out-patient department.

Fifth admission, December 10, 1942. Patient admitted for recurrence of epigastric pain and one episode of gross hematemesis. He was treated conservatively. Alcohol test meal revealed maximum free and total acidities of 45 and 55, respectively.

Anterior vagotomy in this case resulted in no appreciable acid diminution and in only a temporary alleviation of clinical symptomatology.

Case 4. F. M. (M.S.H. No. 435856, O.P.D. No. 38–5311). First admission, November 4, 1938. This 40 year old male patient was admitted with a 10 year history of burning postprandial epigastric pain, relieved by milk and alkalies, and a loss in weight of 30 pounds. Gastrointestinal series had revealed the presence of a duodenal ulcer. Physical examination showed a chronically ill male with moderate right upper quadrant tenderness. The blood pressure was 135/90, hemoglobin 100 per cent, blood urea 26 milligrams per cent, blood Wassermann, negative. Rehfuss test meal and fasting night gastric secretion revealed maximum acid figures of 48/86 and 98/116, respectively. Subtotal gastrectomy plus anterior vagotomy was performed, and the specimen of tissue removed revealed nerve tissue without pathological change. The postoperative course was complicated by the development of a duodenal leak with infection of the drainage tracts. Complete recovery ensued, and the patient was discharged 6 weeks after operation.

Second admission, February 5, 1939. Readmitted for upper abdominal pain and vomiting. Physical examination was negative, except for a slight tenderness about the umbilicus. The stool contained no occult blood. The Rehfuss test meal revealed a maximum acidity of only 45 total and 33 free. The patient improved upon a Sippy regimen.

Third admission, January 17, 1940. Patient complained of slight dizziness and abdominal cramps. A gastrointestinal x-ray film follow-up in the out-patient department failed to show the presence of jejunal ulceration. An insulin test showed no preliminary (fasting) acidity; the test acidities were 50 total and 44 free at 1¾ hours, and 20 total and 10 free at 3 hours.

The persistence of an acid response to insulin indicates that some of the vagal supply remained. This fact was of course known from the operative procedure performed, but it serves to corroborate the validity of the response to insulin as an index of persistent vagal innervation. The hypoacidity present after operation may not be attributed to the partial vagus section but rather to the subtotal resection of the stomach which is sufficient in itself to account for the diminution in gastric acidity. The response to gruel in the ordinary Rehfuss test meal, which does not depend upon vagus integrity, also showed low acid values.

Case 5. R. S. (M.S.H. No. 474310, O.P.D. No. 36–785). First admission, July 10, 1937. This patient was a 41 year old woman who gave an 8 year history of abdominal pain, nausea, vomiting, melena, and hematemesis. The general physical examination was negative. The stools were negative for blood. A gastrointestinal series was negative except for the possibility of a diverticulum of the second portion of the duodenum. The Rehfuss test meal showed a maximum acidity of 98 total and 86 free. She was discharged with a diagnosis of abdominal pain, etiology not determined.

Second admission, October 2, 1937. Readmitted for persistent abdominal pain, in addition to which intermenstrual bleeding had occurred and a fibroid uterus was noted. Gastrointestinal series was again negative and she was discharged with diagnoses of fibromyoma uteri and anxiety neurosis.

Third admission, November 29, 1937. The patient reported the recurrence of epigastric pain and burning. Gastrointestinal series now revealed a slight deformity of the lesser curvature of the stomach although insufficient for the diagnosis of ulcer. The motility was normal. She improved on medical therapy and was discharged.

Fourth admission, April 17, 1939. She was again admitted for epigastric pain, nausea, hematemesis, and melena (history only). The physical examination was essentially negative. The hemoglobin was 70 per cent. The orange-chewing "vagus test meal"[2] showed a maximum total acidity of 86, and free acidity of 70. Exploration was decided upon in view of the persistent symptoms, the history of hematemesis, and the equivocal gastrointestinal x-ray films. At operation, the stomach, duodenum, and gall bladder were all negative. The gastric acidity had been moderately high, and it was therefore thought that vagus section might solve the therapeutic problem. This was carried out by exposing the esophagus below the diaphragmatic hiatus and dividing strands of vagus nerve on its anterior and posterior aspects. Two specimens of excised tissue, examined microscopically, proved to be nerve tissue.

[2]This test is performed by first aspirating the fasting gastric contents. The patient is then permitted to chew half an orange without swallowing any of it, after which gastric specimens are taken every 15 minutes for 3 hours.

Postoperatively, the patient developed a bronchopneumonia from which she recovered without sequelae. She also suffered from marked delay in gastric emptying. The stomach became dilated, and several thousand cubic centimeters of stomach contents had to be aspirated daily. A postoperative orange-chewing "vagus test" revealed maximum acidities of 82 total and 40 free. The gastric retention subsided, and the patient was discharged to the out patient department.

In the out patient department a gastrointestinal series on June 21, 1939 showed no ulcer. There was a 25 per cent 6 hour gastric residue. On July 24, 1939, a methylene blue and alcohol test meal showed maximum figures of 100 total acid and 55 free. Methylene blue was present in all specimens for 3 hours. Gastrointestinal series on September 20, 1939, was unchanged.

Fifth admission, October 18, 1939. The patient was readmitted with complaints of foul breath and regurgitation of food, especially on bending over. Physical examination was still essentially negative. A gruel test meal showed fasting acidities of 12/54 and maximum acidities of 52/58. The orange-chewing test showed no fasting acid and acidity values of 38/70 in the third hour. An insulin test was done, but no hypoglycemia was obtained (the blood sugars were: fasting 90, 40 minutes 90, 3 hours 65) and therefore no free acid response was obtained, in accordance with expectation. On medical therapy, the patient improved and was discharged.

Sixth admission, February 16, 1940. The complaints were epigastric fullness and vomiting, and physical examination revealed no change. A gastrointestinal series again showed a 25 per cent 6 hour residue, but no evidence of ulcer. Slight improvement occurred in the hospital, and the patient was again discharged.

In follow-up, a gastrointestinal series revealed normal motility of the small bowel and stomach on March 10, 1941. On September 10, 1941, she complained of persistent epigastric fullness and occasional vomiting. An insulin test on March 18, 1942, showed the following: there was overnight retention of food; the fasting blood sugar was 70 milligrams per cent, and 35 minutes after insulin injection it was 30 milligrams per cent. The fasting acidities were 25/55. At ¼ hour they were 25/30; at ½ hour 40/60; at ¾ hour 30/60; at 1 hour 80/115; at 1¼ hours 80/115; at 1¾ hours 75/110; and at 2 hours 60/90.

The problem in this case was obviously unsolved by the surgical therapy utilized, namely partial vagotomy. From the point of view of the physiological effects of partial vagotomy, however, the case illustrates rather strikingly that although sufficient of the vagal fibers to the stomach had been severed to produce prolonged delay in the gastric emptying time, a persistent and vigorous acid response to the insulin and other tests remained.

CASE 6. J. A. (M.S.H. No. 488057, O.P.D. No. 34-19954). First admission, May 9, 1942. This patient was a 40 year old male with a 10 year history of postprandial epigastric pain and vomiting. He had lost 60 pounds in weight during this period. Physical examination was negative, except for a thin habitus and an emphysematous chest. Blood pressure was 124/90. The urine and blood Wassermann were both negative. The hemoglobin was 85 per cent. The blood urea was 18 milligrams per cent, blood chlorides 555 milligrams per cent, carbon dioxide combining power 57 volumes per cent, total protein 6.9 milligrams per cent. The electrocardiogram was negative. A gastrointestinal series revealed a deformed duodenal bulb. Test meals before operation showed the following:

Test meals	Maximum acidity (free/total)
Alcohol	35/50 (Fasting—55/70)
Gruel	40/60
Night	55/90
Insulin	112/118 (Blood sugar minimum: 25 mg. per cent)

Posterior gastroenterostomy with anterior vagotomy was performed by Dr. Percy Klingenstein. The upper end of the stomach was exposed at the lower end of the esophagus. All areolar tissue was divided down to the muscularis. A typical posterior gastro-enterostomy was then performed. Moderate gastric retention was present post-operatively to the 14th day. Postoperative test meals showed the following:

Test meals	Maximum acidity (free/total)
Alcohol	10/30
Insulin	90/101 (Blood sugar minimum: 30 mg. per cent)

Follow-up notes, July 8, 1942. The patient gained 26 pounds and complained only of slight regurgitation after breakfast. December 23, 1942. There has been an additional gain of 12½ pounds. No complaints.

This case also demonstrates a definite acid response to insulin after partial vagotomy, with values only slightly lower than preoperative figures. How much the vagotomy contributed to the symptomatic improvement it is impossible to state, since we know that gastroenterostomy alone is quite able to effect such improvement.

THE VALUE OF PARTIAL VAGOTOMY

A critical review of the literature leaves one unconvinced as to the value of partial vagotomy in the therapy of peptic ulcer. Even Latarjet, whose procedure is most likely to sever all the vagus supply to the stomach, advocated an additional surgical procedure, gastroenterostomy. In the series reported by Winkelstein and Berg, 26 cases out of 34 developed achlorhydria. Of these, however, only 16 were immediate; the other 10 developed achlorhydria later. It is difficult to see how section of a nerve can produce a delayed loss of function in the organ innervated. One would expect an immediate result or none at all. On anatomical grounds, moreover, the entire posterior mucosal surface of the residual stomach retained its innervation and therefore would continue to secrete acid if severance of the nerve supply were the only therapeutic factor involved. The high percentage of cases in which achlorhydria was achieved, and the beneficial therapeutic effects reported by these authors, must therefore

be attributed to the partial gastrectomy rather than to the partial vagus section.

The work on pouch dogs previously reported by us demonstrated that secretory impulses arising in the central nervous system continue to be transmitted to the stomach pouch even after loss of most of the vagal innervation. One should also recall that much of the fundamental work done by Pavlov and his school on the conditioned reflex involved the use of a pouch which has been demonstrated to have been deprived of the bulk of its vagal supply. It is difficult, in light of this, to visualize how one can hope to eliminate the so called psychic element in the therapy of peptic ulcer by partial vagus section. Moreover, the elimination of the psychic and nervous phases of secretion *in toto* would not necessarily solve the problem, since the other (chemical) phases of gastric secretion may very well be factors of such magnitude as to overshadow completely the psychic phase in importance. This was demonstrated in the pouch dogs of our experimental series, in which Heidenhain or completely denervated pouches, as often as not, gave postprandial responses indistinguishable from those of pouches with varying degrees of innervation. Therefore, too much cannot be expected therapeutically even from complete vagus section.

The conclusions to be drawn from the 6 cases reported here are limited, as they are in any clinical study in a small series of isolated cases. Most of the cases presented exceedingly complex problems, and vagotomy was employed only as a last resort. The series was shortened by reluctance to continue a procedure which seemed to offer little therapeutically, and which introduced a definite increase in operative risk. From a therapeutic point of view it would seem that *complete* vagotomy would have more to offer in reducing the acid or producing achlorhydria, than *partial* vagotomy. Whether this would be offset by the disadvantages of motility alterations observed in several of our cases is open to speculation. However, complete vagotomy is extremely difficult to achieve technically without appreciable increase in the operative danger. Through a transpleural approach the exposure is good, and complete division of the vagus supply would therefore seem easier through this route. Actually, even with the best of unilateral exposure, it is far from a simple matter to expose all sides of the esophagus, and because of the rich branching and anastomosing of nerve fibers about the lower esophagus, which some anatomists have described as an esophageal plexus, many of the smaller branches will escape the most determined and careful operator. This approach also severs the vagus trunks proximal to the large branch to the celiac plexus which supplies the remaining abdominal viscera, and it therefore may interfere with the function of these organs. The risk of the transpleural supradiaphragmatic approach is a real one and the procedure should accordingly not be considered lightly. Subdiaphragmatically, complete vagotomy is more difficult to achieve since the problem of rotating the esophagus or upper stomach to afford access to all sides is clearly neither simple nor atraumatic. Actually, none of the cases in our series had a complete vagotomy although this was attempted in two instances. Anatomical dissection in one case and the insulin test in all six proved the persistence of vagal fibers.

The benefits derived from partial vagotomy in our series are questionable. The first case, in which supradiaphragmatic vagotomy was performed, was certainly unimproved and subsequently developed a recurrent jejunal ulcer. The second died. The third, a gastrojejunal ulcer, had a recurrence of symptoms 9 months after anterior vagotomy and the Stierlin procedure were performed. The fourth, 3½ months after subtotal gastrectomy and anterior vagotomy, developed recurrence of pain and vomiting although he has been well since. However, one cannot say that the partial gastrectomy alone would not have done equally well. The fifth case (in which partial vagotomy alone was performed) certainly was not improved clinically, and instead developed difficulties in motility after the procedure. The sixth case is too recent to draw conclusions as to the therapeutic effect. All cases showed a persistence of acid response to insulin proving not only that vagotomy had been partial, but that little reduction in the nervous phase of gastric secretion can be expected from such partial vagotomy. It is true that most of the cases presented exceedingly difficult problems, but in the present state of our knowledge there is little reason to employ the procedure in the simpler variety of cases, and it certainly does not warrant incurring the added risk involved in the transthoracic or even the subdiaphragmatic vagotomy.

SUMMARY AND CONCLUSIONS

1. A brief review of the literature on gastric vagotomy and its experimental and clinical effects is presented.

2. Experimentally, it is shown that little diminution in the nervous phase of gastric secretion is to be expected from partial vagotomy, while the other (chemical) gastric secretory phases are entirely unaffected. The insulin test is an unfailing

means of determining the persistence of part of the gastric vagus supply.

3. Six clinical cases are presented in which vagotomy was performed either alone or in conjunction with some other operative procedure. The therapeutic problem in most cases was difficult and had not responded to ordinary measures. In 3 cases the lesion was a gastrojejunal ulcer following partial gastrectomy, in 2 it was a duodenal ulcer, and in 1 there existed severe functional complaints without any demonstrable organic lesion. In only 2 cases was complete vagotomy attempted, but in neither of these was it achieved. The validity of the insulin test as an index of persistent vagal innervation was upheld by the studies in these cases.

4. In none of the cases was clear cut evidence of beneficial therapeutic effect obtained. Instead, a definite increase in operative risk and morbidity was encountered. The inefficacy of the procedure clinically bears out what had already been observed in the laboratory, namely, that partial vagotomy does not influence the nervous phase of gastric secretion significantly, and that even if it did, the other secretory phases may overshadow the nervous phase to such an extent as to render it unimportant.

5. Accordingly, gastric vagotomy alone cannot be recommended as a therapeutic procedure; complete vagotomy because of its risk, difficulty of accomplishment, possible effects on motility, and only questionable influence on secretion; and partial vagotomy because of the absence of any beneficial effects whatever.

* * *

Following completion of this paper, 2 cases of supradiaphragmatic bilateral vagotomy were reported by Dragstedt and Owens[3]. Both of these patients appeared to have been benefited by the operation, but the period of observation was of only a few months' duration. There was a considerable reduction in night secretion but not total elimination. Neither the insulin test nor any other test for vagal continuity was performed.

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THE SURGICAL TREATMENT OF CORROSIVE GASTRITIS

KARL A. MEYER, M.D., F.A.C.S., and FREDERICK STEIGMANN, M.S., M.D.,
Chicago, Illinois

CORROSIVE gastritis results from the ingestion of corrosive substances, the most common of which are those most frequently used in homes and industry, namely lye (alkali) and mineral acids.

The surgeon usually encounters patients when they begin to suffer from the sequelae of corrosive gastritis. These sequelae are manifested by symptoms of pyloric obstruction. Since these sequelae may not be evident until many months following the intake of a corrosive substance, the patients often do not associate their present symptoms with the past mishap. Therefore the patient should be asked directly as to a possible intake of a corrosive substance since otherwise he might not regard such an occurrence as significant.

The nature of the injury sustained by the esophageal and gastric mucosa from ingestion of a corrosive poison determines the future course and the type and time of appearance of symptoms. As a rule, the more severe the initial symptoms, the stormier the immediate course, the more marked the sequelae, and the sooner the symptoms of obstruction will appear. Weak corrosives may give rise to only mild secondary symptoms.

The reaction of the corrosive used, whether acid or alkaline, has a particularly important bearing on the site of the permanent damage. Symptoms of dysphagia will appear more often and much sooner after the ingestion of an alkaline corrosive (lye) than after an acid. Indeed, in most instances of corrosive gastritis due to an acid, in our series, the patients presented themselves not because of dysphagia but because of symptoms of gastric obstruction. On the other hand, following lye ingestion, dysphagia was the earlier and more prominent symptom.

The sequelae of corrosive poisoning are characteristically determined by the type, amount, and concentration of the substance swallowed, and by the state of the stomach when the ingestion of the corrosive occurred; i.e., whether full or empty. The ingestion of lye results in an involvement of both the esophagus and stomach. The esophagus, however, is more severely involved since the lye is somewhat more diluted when it reaches the stomach. Acids, on the other hand, seem only to scorch the esophageal mucosa during their rapid course through the esophagus, but corrode the gastric mucosa with which they are in longer contact. Larger amounts and higher concentrations will obviously cause greater damage. In case of a full stomach, the gastric contents dilute the corrosive agent so that the damage may be minimal and involve only the pyloric region and the lesser curvature. When the stomach is empty and contracted during the swallowing of a corrosive liquid, the latter comes in contact with the entire gastric mucosa, particularly that of the antrum and pars media, so that marked corrosion occurs in these areas. If perforation with resulting peritonitis does not occur in the corroded areas, ulceration with secondary cicatrization of the walls ensues resulting in marked narrowing and ultimately in stenosis of these portions. Thus, the end-result of a healed corrosive gastritis is at best a pyloric stenosis with involvement of the distal part of the antrum, and at worst a gastric stenosis with involvement of the distal half or more of the stomach. Regardless of the extent of involvement, surgical intervention for creation of a new opening becomes necessary in most instances.

Once the diagnosis of a corrosive gastritis has been made, the question arises as to what surgical procedure is indicated. To answer the latter at times is difficult. As a rule, if the patient presents himself to the clinician with signs of pyloric obstruction several months after drinking the corrosive liquid, the pathologic sequelae of that mishap may be mended by a simple gastroenterostomy. If, however, the corrosive agent was ingested only a short time before, the condition is acute and the surgical procedure will depend on the finding at laparotomy. Thus, if at operation the surgeon finds the stomach edematous and friable with much perigastric inflammation and adhesions, it is better to terminate the operation as a jejunostomy and postpone the operation on the stomach for a later date. Such a step has two advantages. First, it permits the patient to keep in good nutritional status by means of jejunostomy tube feedings. Second, it avoids surgical handling of the stomach during a time when any surgery may be hazardous

From the Departments of Surgery and Therapeutics of the Cook County Hospital, the Department of Surgery, Northwestern University Medical School, the Department of Internal Medicine, University of Illinois College of Medicine and the Cook County Graduate School of Medicine, Chicago.

because the gastric wall is edematous and inflamed and thus may not permit good suturing with resulting leakage leading to fatal peritonitis. The latter fact has been stressed particularly by various German surgeons (4, 5). In some instances, a prior jejunostomy will permit the stomach to rest and thus aid in the healing process and in the better demarcation between normal and affected parts of the gastric wall. Moreover, in some instances in which the pouch formed by the uninvolved part of the stomach is small and thus presages difficulty during an attempt at anastomosis, a previous jejunostomy will keep the patient nourished, while the patient is fed orally until he vomits. Because of the complete gastric obstruction the oral feeding can be considered only as a "sham feeding" which actually serves only to distend the gastric pouch (Case 2) so that it becomes better suited for gastroenterostomy. If, however, at laparotomy the stomach, except for the pyloric obstruction, is found only slightly affected, in spite of the recent history, then an immediate gastroenterostomy may be performed. In patients with corrosive gastritis, gastroenterostomy is not a generally prohibited procedure as in those with duodenal ulcer, because, due to the destruction and searing of the gastric mucosa by the corrosive agent, secretion of acid is usually eliminated; a fact which diminishes the possible incidence of marginal ulceration.

In spite of some opinions to the contrary (2), we believe that jejunostomy should be performed in these cases whenever the surgeon at laparotomy has even the slightest doubt about the condition of the gastric walls. Friability, inflammation and edema of the gastric walls spells failure for any attempt at gastric surgery. Haste to perform the gastro-enterostomy is dangerous. A preliminary jejunostomy may mean the difference between success and failure in that it permits replenishing the patient's nutritional losses, and healing of the gastric walls and better demarcation of the affected parts. We believe that if vomiting starts soon after the ingestion of the corrosive agent and is not relieved by a medical regimen, preliminary jejunostomy is indicated even though one might consider such a procedure superfluous with the present day facilities for intravenous alimentation. That this does not hold true was recently demonstrated by the case of a 3½-year old child who drank a corrosive substance by mistake and who came under our observation about 4 weeks after the onset of vomiting. During this time she was given only intravenous fluids with occasional plasma and blood transfusions. She lost 10 pounds and was quite emaciated and protein deficient when operated upon. At operation, only the fundic portion of her stomach was found uninvolved. An anterior gastroenterostomy was performed. The child made an uneventful recovery but is regaining her weight only slowly even though she eats fairly well; a fact which may be blamed on the prolonged starvation before operation.

Fig. 1. Large stomach due to pyloric obstruction following hydrochloric acid ingestion.

CASE REPORTS

The following case reports are representative of patients who came to the hospital because of sequelae of corrosive gastritis.

E. W., a 50-year old male, was admitted to the hospital with a history that for the past 3 days he had been drinking heavily and about 3 hours ago he took a glass of muriatic acid by mistake. A doctor was immediately called who gave him a glassful of sodium bicarbonate solution. Since then he had frequent watery evacuations of brownish color mixed with blood. Physical examination revealed a middle aged white man of acutely ill appearance and in great pain; pulse, 140; temperature, 98 degrees; blood pressure, 130/0. There was no excoriation of the lips, the palate and uvula were edematous and swollen, the pharynx looked red and there was some tenderness over the epigastrium. There were no other findings.

On entrance to the hospital the hemoglobin was 85 per cent, red blood cells 4,430,000 white blood cells 14,200 with 85 per cent polymorphonuclear cells. The urine was negative. After 4 days the temperature which had reached

Fig. 2. Roentgenogram showing marked gastric deformity following the drinking of hydrochloric acid on fasting stomach.

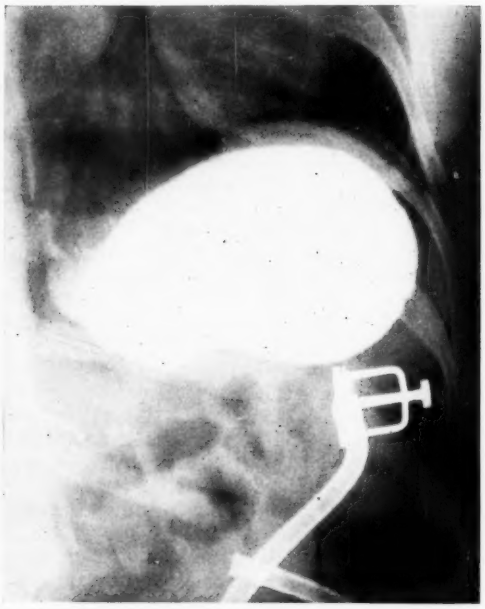

Fig. 3. Same gastric "pouch" as in Figure 2, 3 months after jejunostomy feeding and oral "sham" feeding. Note enlargement of gastric pouch and jejunostomy tube *in situ*.

101 degrees shortly after entrance became normal. The patient was given fluids intravenously and went along fairly well except for some difficulty in swallowing, which gradually cleared up. He left the hospital 10 days later, being able to take food without complaints.

He returned to the hospital 3 months later complaining of vomiting, epigastric pain, and belching. These symptoms supposedly had been present for the past 2 months while he was under observation at the gastrointestinal clinic. X-ray films of the stomach revealed a high-grade pyloric obstruction (Fig. 1). The patient was therefore admitted to a surgical ward. Examination there was essentially negative except for signs of marked weight loss. Pyloric obstruction on the basis of corrosive poisoning was diagnosed and the patient was operated upon. At operation the wall of the lower half of the stomach was found to be very thick, the mucosa appeared scarred and ulcerated, and the pylorus was stenosed. A posterior jejunostomy was performed. Patient made an uneventful recovery and left the hospital 2 weeks later.

L.S., female, 35 years of age, was admitted to the hospital with the history of having drunk, 2 months prior, a small amount of hydrochloric acid with suicidal intent. She was rushed to a physician's office where her stomach was lavaged. Following that she experienced mild substernal and epigastric distress which in time became associated at first with regurgitation and later with vomiting of everything she ingested. Sedatives and antispasmodics gave her no relief. Physical examination of the patient was essentially negative. An x-ray examination of the stomach revealed that there was a marked deformity of the lower two-thirds of the stomach with only a small portion of the fundus being intact (Fig. 2).

After suitable preparation an exploratory laparotomy was done at which time marked perigastritis was noted. The stomach itself was "mushy" and the uninvolved portion almost too small to permit gastroenterostomy. Therefore a jejunostomy was done and the patient was fed through a tube for 3 months. At the same time she was fed orally in order to distend the uninvolved part of the stomach (Fig. 3). All the oral feeding was vomited. At the end of 3 months a second laparotomy was done, and at that time an anterior gastroenterostomy was performed. The patient made an uneventful recovery except for some slight esophageal stricture which responded to dilatation. She has been doing well since (8 years).

M. S., male, 52 years of age, was admitted to the hospital with complaint of weight loss (15 lbs.) for 1 month and vomiting for the past 4 days during which time he was not able to keep down even liquids. The physical examination revealed only an emaciated white male with no other findings. The x-ray examination of the stomach was reported, "Infiltrating growth involving the lower three-fourths of the stomach, dilatation of the cardia, pylorus stiff and unchanging. No barium passed through at the end of 6 hours." Diagnosis: Far advanced malignancy of the stomach with complete obstruction (Fig. 4). The patient was then transferred to surgery as a case of carcinoma of the stomach.

Additional history in the surgical ward revealed that several weeks prior the patient drank inadvertently some cleaning polish containing muriatic acid which he mistook for wine. The diagnosis was changed, therefore, to corrosive gastritis and the patient was prepared for laparotomy. At operation the lower third of the stomach appeared constricted with marked dilatation of the upper two-thirds. An anterior gastroenterostomy was performed. Patient made

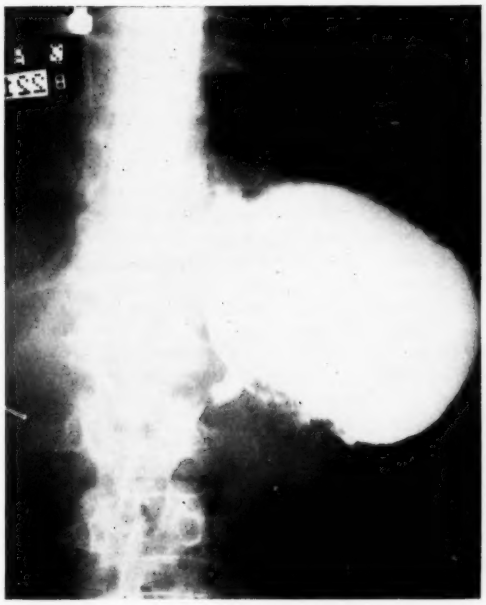

Fig. 4. Large fundic portion of stomach with lower half represented only by a small tube-like projection, due to scarring following the intake of "shoe polish cleaning fluid."

Fig. 5. Complete obstruction of lower portion of stomach after child drank a fluid containing zinc chloride.

an uneventful recovery and is getting along well, being able to eat the average bland diet. X-ray examination of the stomach 2 months after the operation revealed a large well functioning stoma.

M. D., 3½-year old child, while playing in the yard, drank some liquid from a discarded bottle. This liquid was found later to contain zinc chloride. She was rushed to a hospital in the vicinity where gastric lavage was performed, after which she was sent home. Several days later the patient began to vomit everything she ingested including liquids. She was admitted to a hospital where she was given intravenous fluids for about 2 weeks before she was sent to Cook County Hospital.

An x-ray examination of the stomach taken at the outside hospital and also at the County Hospital revealed a complete obstruction of the distal part of the stomach with the remaining fundic pouch only about the size of half a dollar (Fig. 5). The child was prepared for operation with plasma, whole blood, and fluids. At exploratory laparotomy the distal two-thirds of the stomach were found completely stenosed. An anterior gastroenterostomy was performed on the remaining small pouch with great difficulty. The child made an uneventful recovery and has been gaining weight slowly. Follow-up x-ray examination showed that the small pouch was enlarging and that the stoma was functioning well.

These 4 representative histories of patients with corrosive gastritis seen at the Cook County Hospital give first, a clear picture of some of the underlying causes. Second, they demonstrate the different symptoms and the variable onset of the sequelae of corrosive gastritis. In most instances this condition is found in individuals of over middle age and therefore the condition is most often diagnosed as carcinoma of the stomach.

In spite of the fact that surgery is indicated in both conditions so that one might argue that the exact diagnosis is unimportant, we believe that it is rather of great importance to make an accurate diagnosis before laparotomy is done inasmuch as both the doctor and the patient's family are in a different frame of mind when an operation is performed from a curative than from a palliative point of view. Since corrosive gastritis has a very good prognosis if treated properly, it is obvious that the latter diagnosis carries with it much more assurance to the patient and a much better prognosis than the diagnosis of carcinoma.

Corrosive gastritis is diagnosed as gastric carcinoma not only because of suggestive appearance of the x-ray films but also because of symptoms of continuous vomiting, marked weight loss, and achlorhydria. However, there is no, or only rarely, blood in the stool of patients with sequelae of corrosive gastritis. It behooves the clinician, therefore, to evaluate carefully the obtained history and physical findings in patients who present

"malignant findings" but who don't seem to quite fit into the carcinoma group (1).

Corrosive gastritis is one of the many gastroenterological conditions in which anamnesis is so important because except for the history of a possible ingestion of some such substance, there is rarely any other way by which it can be diagnosed before operation. In many instances, moreover, the diagnosis may not be made by the surgeon even at operation if he is not aware of such a condition. The operating surgeon may see an unusual picture having more of an inflammatory than malignant character but the true nature of the pathology may not be considered unless he is familiar with such a condition or keeps it in mind (3). Not only is it important to differentiate between corrosive gastritis and carcinoma from the point of view of prognosis but also from the point of view of treatment inasmuch as corrosive gastritis requires different preparation and a different type of operation.

Further, in patients suffering from the sequelae of corrosive gastritis there is no danger if surgery is delayed while in the meantime the patient is built up. Then, too, in many of these cases of corrosive gastritis two-stage operations may be necessary; i.e., primary jejunostomy and secondary gastroenterostomy at a later date, while in carcinoma this is rarely advisable. The patient with corrosive gastritis is not an emergency case and all possible measures should be taken to build him up to an optimum before surgery is undertaken. In contrast to patients with carcinoma of the stomach, patients with corrosive gastritis should be watched for some time before surgery is attempted so as to give the corroded area a chance to delineate itself so that at operation the surgeon can tell with certainty the normal from the affected parts.

SUMMARY AND CONCLUSION

Corrosive gastritis is a pathological condition of the stomach which follows the ingestion of some corrosive substance and which usually requires surgical intervention for its relief. The condition, even though comparatively rare, is not as infrequent as previously thought and occurs quite commonly among people of the lower social strata as seen in charity hospitals. The sequelae of ingestion of a corrosive substance may occur anywhere from several days to several months later. It is therefore quite common that the patient when seeking relief from his gastric symptoms fails to recall the time of the mishap, that is, when he ingested the substance.

Corrosive gastritis is therefore another condition in which is stressed the value of securing a good history in patients with gastrointestinal complaints. All patients with corrosive gastritis whom we have seen required surgical intervention for relief of the gastric obstruction. Gastroenterostomy rather than resection may be done inasmuch as the dangers of secondary gastrojejunostomy ulceration are minimal since in these stomachs there is no free acidity present. Patients with corrosive gastritis have to be prepared carefully and for a long time, if necessary, by jejunostomy feedings, for the final operation on the stomach. In some cases with very small fundic pouches "sham feedings" have to be given in order to distend this portion sufficiently to permit the gastroenterostomy.

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HOOK TRACTION UNDER ZYGOMATIC ARCH IN CERVICAL SPINE INJURIES

WILLIAM T. PEYTON, M.D., HARRY B. HALL, M.D., and LYLE A. FRENCH, M.D.,
Minneapolis, Minnesota

SKELETAL skull traction for the treatment of cervical vertebral injuries was first reported by Crutchfield in 1933 (3). Since then McKenzie, Hoen, Cone and Turner, Barton, Selmo, Neubeiser, and others have described methods and apparatus for obtaining skeletal traction on the skull in the treatment of fractures, dislocations, and fracture dislocations of the cervical spine. The purpose of this paper is not to discuss the relative merits of the different methods advocated and in use today but to describe a simple apparatus for skeletal traction.

Most methods and apparatus have special advantages and all those described have been effective in maintaining traction on the cervical spine. However, all methods except those described by Neubeiser and Selmo require either burr holes in the calvarium through which wires are passed down to the dura or tongs inserted down to the inner table of the skull. Both Neubeiser and Selmo have described methods by which traction is applied to the zygomatic arch on both sides of the skull. Neubeiser reported 1 case in which he used stainless steel fish hooks under the zygomata. Selmo described the application of blunt hooks under each zygomatic arch with a special type of triangular bar used to connect the hooks.

The method described here concerns the use of fish hooks, inserted under each zygomatic arch, to which traction can be applied. Since September, 1940, we have obtained skeletal skull traction for lesions of the cervical spine by the use of stainless steel (No. 5) fish hooks from which the barbs have been removed. One such hook is inserted under each zygomatic arch. The hooks can be inserted and the traction applied without moving the patient from his bed. With local or intravenous anesthesia the points of the barbless hooks are inserted under each zygomatic arch about 1 inch anterior to the external auditory meatus. Lead-up wires from the hook eyes are carried to the top of the head and connected either to a wood cross bar, 8 inches long and 1 inch square, or to a triangular traction rod. A rope is tied to the center of the bar or rod and hung over a pulley at the head of the bed. Weights are tied to the end of the rope, and the head of the bed is elevated, so that the patient's body weight is utilized for countertraction. Fifteen pounds divided between two hooks is the maximum weight used in any of our cases. Crutchfield (4), however, reports that he has found 18 pounds inadequate for the reduction in some cases and has used as much as 25 pounds. This is still well within the maximum weight which No. 5 stainless steel fish hooks will bear without straightening out, since by test it was found that they could withstand a pull of 20 pounds on each hook.

With the fish hooks in place, the patient may turn on his side and be given nursing care without difficulty. Disfiguring scars are not left at the site of the hook insertion. In fact, after the hooks have been removed, it frequently becomes difficult to identify the site of insertion. After trying various types of skeletal skull traction, we believe that fish hook traction is the most satisfactory. Eleven patients have been treated by this method without untoward event except that in 1 case it was necessary to remove the hooks after 3 weeks, because there was a mild inflammatory reaction about one hook. Two case histories in which this method proved to be especially efficient are as follows:

CASE 1. N. N., U. H. No. 723545. A 62 year old white male walked into the Outpatient Department manually supporting his head. He found that this support gave him relief of neck pain from which he had otherwise suffered. The patient had been injured 31 days previously and had been treated by bed rest only and with pillows, while acute flexion of the neck was maintained. On examination it was found that the patient held his head flexed forward about 25 degrees. There was marked tenderness over the spinous process of the 5th cervical vertebra. There was limitation of motion of the head in all directions. Weakness was noted in all extremities but was more marked in the upper extremities, with the right hand very weak. Roentgenological examination showed a compression fracture of the 5th cervical vertebra with anterior angulation of the cervical spine at this level (Fig. 1). A barbless fish hook was inserted under each zygomatic arch, and traction was applied. The angulation was overcome in 10 days with

From the Department of Surgery, University of Minnesota Hospitals, Minneapolis, Minnesota.
Dr. French now a Captain in the U. S. Medical Corps.

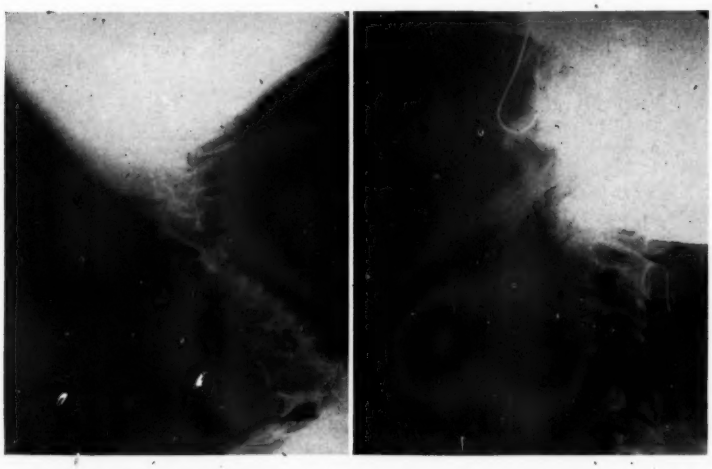

Fig. 1, left. Case 1. Roentgenogram showing the angulation of the cervical vertebrae at the fracture site 1 month after injury and before any traction was applied.
Fig. 2. Case 1. Roentgenogram showing the correction of the angulation 10 days after application of fish hook skeletal traction.

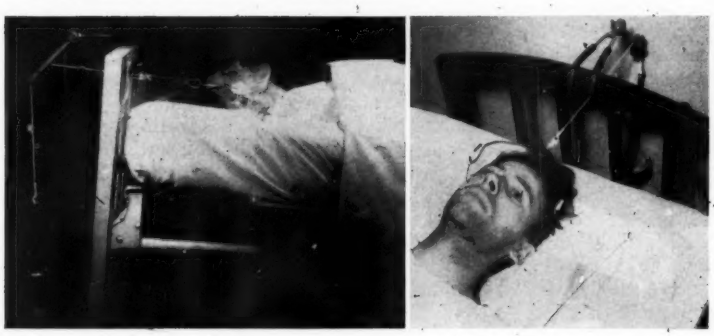

Fig. 3, left. Case 1. Photograph showing patient with fish hook traction in place. Note the hyperextension of the neck obtained.
Fig. 4. Photograph showing fish hook traction in place on patient who had had halter-type of traction which produced ischemic ulcers under the chin.

15 pounds of traction (Fig. 2). After the traction was maintained for 4 weeks, a spinal fusion was performed, and the traction was continued after operation to prevent recurrence of the angulation. The hooks were removed 2 weeks after operation and a plaster jacket incorporating the neck and head was applied.

Skeletal traction with hooks under the zygoma was especially suitable in this case because with traction so far forward on the skull (Fig. 3), maximum hyperextension was obtained, and since the patient was not admitted to the hospital until 1 month after his injury, it was necessary to use 15 pounds of traction to reduce the deformity. Halter type of traction, with so much weight, is very uncomfortable and if maintained may result in the development of ischemic ulcers under the chin or occiput (Fig. 4).

Case 2. C. S., U. H. No. 721082. A white male, 20 years of age, suffered a dislocation of the 2d cervical vertebra and multiple fractures of the mandible. This man obviously could not be treated with head traction of the halter type. Fish hook traction was applied and proved to be most satisfactory. Interdental wiring was done during the period of skeletal traction without disturbing the reduced cervical dislocation.

CONCLUSION

Skeletal skull traction by means of fish hooks inserted under the zygomatic arch is simple, safe,

and easy to apply. The procedure can be performed without moving the patient from his bed. The apparatus is obtainable at any hardware or sporting goods store. They can be easily inserted by physicians not especially trained in surgery. The cost is negligible. It would seem that this form of skeletal traction would be especially useful to the armed forces. Steel hooks similar to the barbless fish hooks previously described could be made easily in any machine shop ashore or aboard ship.

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POSTERIOR MEDIASTINAL GOITER

J. M. MORA, M.D., F.A.C.S., H. J. ISAACS, M.D., S. H. SPENCER, M.D., and L. EDIDIN, M.D, Chicago, Illinois

PARTIALLY intrathoracic goiters occur relatively often, especially in areas of endemic goiter. Their incidence is placed at about 12 to 20 per cent (2). Completely intrathoracic goiters are much rarer; Wakely and Mulvany had 3 such cases in 1,200 consecutive thyroidectomies. Hunt reported 3 totally intrathoracic thyroid masses in 651 consecutive thyroidectomies. In Pemberton's series of 4,006 cases, 25 were intrathoracic, and in Crile's series of 11,800 thyroidectomized patients there were 97 cases of this type.

The rarest of the intrathoracic goiters is the type found in the posterior mediastinum. Only 6 such cases have been previously recorded. The Berards reported a case of what they described as an "endothoracic and retroesophageal basedowified goiter" which occurred in a 55 year old woman with syphilitic aortitis. Recovery followed removal of the mass through the usual collar incision under local anesthesia.

A second case was reported by Von Haberer in 1938. His patient was a 39 year old woman who, for 20 years, had had "respiratory troubles" with moderate enlargement of the thyroid. In 1935 the visible portion of goiter was removed, with no improvement in the patient's symptoms. X-ray study of the chest 2 years later showed a homogeneous shadow of round outline, located in the mediastinum on level with the fourth rib. (The left apex appeared opaque.) A lateral view showed this shadow was close to the posterior thoracic wall, but the trachea appeared neither deviated nor compressed. A tumor was diagnosed and radiotherapy advised. Von Haberer, however, noted slight movements of the supposed tumor with deglutition, and advised operation. The sternum was divided down to the third interspace. No tumor was felt, but from the lower part of the right thyroid lobe, a row of nodules led into the posterior mediastinum, ending in an intrathoracic mass the size of a child's head. The mass was finally freed and removed after rupturing a large cyst. The final diagnosis was colloid goiter. Uneventful recovery ensued, with complete relief of all symptoms.

Roholm's patient was a 55 year old woman with mild thyrotoxicosis and no thyroid enlargement.

Roentgenography of the chest revealed a sharply defined massive tumor (size of a large fist) in the posterior mediastinum, between the spinal column and the displaced esophagus. There were no local pressure symptoms. The x-ray findings suggested differential diagnostic consideration of lung tumor. Aspiration biopsy (with trocar) provided the correct diagnosis—"colloid goiter." This patient was not operated upon.

From the Mt. Sinai Hospital, Chicago, Illinois

Two additional cases were reported by Urban from the Catholic Hospital in Linz (Austria). No details are given save that they occurred in a consecutive series of 8,500 goiter operations and both were successfully removed through collar incisions.

The sixth case was reported by Henschen who, in discussing Reufer's paper, stated he had had 1 case of posterior mediastinal goiter in 6,000 consecutive thyroidectomies. He described this case as "an intrathoracic retrovisceral retroesophageal thyroid connected to the cervical thyroid by a thin process." His patient exhibited gastric and cardiac disturbances—probably due to pressure on the vagi. Removal of the intrathoracic mass cleared up all symptoms.

The history of our case, the seventh to be recorded, follows:

Mrs. R. G., No. 120,883, a 55 year old white woman, was admitted to the hospital November 20, 1942, complaining of increasing weakness, nervousness, palpitation, and weight loss. These symptoms came on rather rapidly some 5 months before admission to the hospital. Despite a fairly good appetite she had lost 20 pounds in this period. Closer questioning disclosed that she had not been feeling well for about 8 years, having noted increasing fatigue on slight exertion, profuse perspiration, heat intolerance, and tremor of fingers. From time to time she would have bouts of marked nervousness, weakness, irritability, and palpitation, all of which she attributed to the menopause. A few weeks before entering the hospital she had become aware of a nonproductive cough and some difficulty in swallowing. She had been seen and studied in the course of the 8 years before admission to the hospital by a number of physicians (including the Mayo Clinic), all of whom found on x-ray examination of the chest, a large shadow occupying the right upper lung field. She was advised to do nothing about this mass. A number of basal metabolic rate determinations had been made and the patient told they were normal.

The past history was irrelevant. She had had 3 normal pregnancies, and the children were alive and well. The menses had ceased 9 years previously. There was no family history of goiter.

The salient physical and laboratory findings were as follows: the pulse rate varied from 112 to 128, the blood pressure from 160/76 to 180/80. There was no thyroid tissue palpable in the neck, but the trachea was displaced slightly to the left. Examination of the lungs disclosed moderate impairment of resonance over the right upper anterior chest. The cardiac rate varied from 112 to 128 with normal rhythm, no enlargement, and a short, soft, blowing systolic murmur was heard over the entire precordium. There was marked tremor of the outstretched fingers, and slight pitting edema above the ankles.

Numerous urinalyses showed no abnormalities save an occasional trace of albumin and a few white corpuscles. The red blood count was 4,400,000 per cubic millimeter,

Fig. 1. Roentgenogram of chest (anteroposterior view) showing large globular mass occupying right upper lung field.

white blood cells 5,500, with 68 per cent segmented cells, 28 small lymphocytes, and 4 monocytes. The hemoglobin content was 13.1; there was moderate anisocytosis and hypochromia. Blood chemical studies revealed: sugar, 90 milligrams per 100 cubic centimeters; nonprotein nitrogen 20; and cholesterol 170 milligrams per 100 cubic centimeters. Five basal metabolic rate determinations varied from +45 to +51.

Roentgen study of the chest disclosed a large globular mass occupying the right upper thoracic cavity; on lateral views this mass was seen to lie in the posterior mediastinum.

The diagnosis at this time was thyrotoxicosis, and the mass was believed to be a large intrathoracic goiter, although Dr. Arendt (the roentgenologist) felt that we could not exclude a neuroblastoma, which so frequently is found in the posterior mediastinum.

The patient was accordingly prepared for operation—she was given 15 minims of Lugol's solution 3 times daily, placed on a high carbohydrate and high protein diet, adequate vitamins, especially B complex, large quantities of fluids, proper sedation and rest. On this regimen the basal metabolic rate fell to +27, the pulse became slower (90 to 100), and the patient gained 9 pounds.

Operation was carried out on December 29, 1942. Intratracheal ethylene anesthesia was used throughout. The neck was opened through the usual collar incision and the strap muscles were separated. Preliminary exploration revealed no thyroid tissue in the neck. On further dissection a small cystic lobe was found on the left, just at the superior thoracic aperture. This was easily and quickly removed. On the right, a thin attenuated pole was found just below the level of the first rib; this was secured and divided between ligatures. On further exploration, a large mass was encountered posteriorly, and lying entirely within the thoracic cage. On careful finger dissection hugging the margins of the mass and with gentle traction upward the tumor was gradually freed. A hemostat was then plunged into the mass, and the liquid and jelly-like contents were removed by suction. This procedure permitted narrowing of the transverse diameters of the thoracic goiter, following which it was easy to deliver the entire mass. The neck was closed with one gauze drain, which was then removed in 48 hours.

Fig. 2. Roentgenogram of chest (lateral view) showing mass lying in posterior mediastinum.

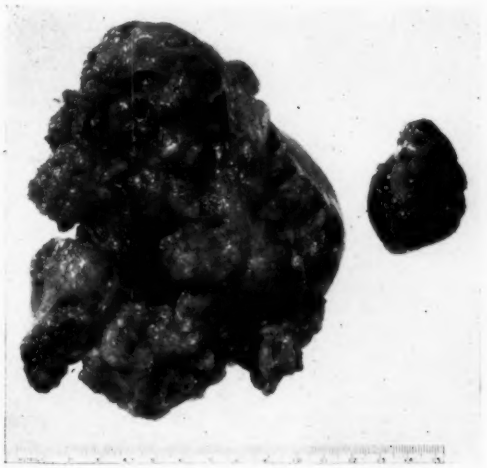

Fig. 3. Photograph of removed thyroid gland showing huge right lobe and smaller left lobe.

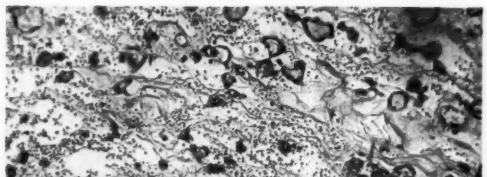

Fig. 4. Low power photomicrograph of section from right lobe, showing diffuse edema of stroma separating acini and many infiltrating lymphocytes. The acini vary in size, but most of them are smaller than normal. They are lined with low cuboidal epithelial cells. Budding is marked.

The patient made a smooth and uninterrupted recovery and was discharged in good condition on the 10th postoperative day. The basal metabolic rate was +3 three weeks after operation and 1 year after operation the rate was +6 per cent. She was quite well at this time and save for a mild arthritis (which she had for many years before the operation), she was able to engage in her usual household and social activities. She had gained 14 pounds in the year following removal of the intrathoracic goiter, and at no time was there evidence of hypothyroidism, parathyroid damage, or injury to the recurrent laryngeal nerves.

The pathological report by Dr. I. Davidsohn was as follows:

The right lobe is an encapsulated previously opened soft mass measuring 12 by 9 by 4.5 centimeters and weighing 218 grams. It consists of soft yellow-brown tissue having the appearance of thyroid tissue. The sectioned surface is moist and glistening and on scraping yields a fairly large amount of colloid. In some places light yellow-brown areas of somewhat firmer consistency are present. They measure up to 5 millimeters in diameter. In some places hemorrhages are seen. In many areas the capsule shows evidence of separated fibrous connections.

The left lobe is also encapsulated measuring 5 by 3 by 2 centimeters, and weighing 21 grams. On sectioned surface it is yellow-red, moist, glistening, and the upper pole presents a calcified node surrounded by an area of fibrosis.

Microscopic: The acini of the right lobe vary considerably in size and configuration. Some are very large. They are lined with flat to cuboidal epithelial cells and are filled with pure staining colloid. In some places there is an abundant hyalinized and edematous stroma scattered throughout these areas and in their vicinity there are many small acini, some of which show active budding and branching. The capsule is infiltrated with lymphocytes in many places. Other areas show evidence of old hemorrhage. Sections from the left lobe show a similar picture. There is also a large area of hyalinized connective tissue surrounded by very small acini and presenting the picture of microfollicular adenoma.

The pathological diagnosis was right lobe, colloid and nodose goiter (intrathoracic); microfollicular adenoma; left lobe, microfollicular adenoma.

Fig. 5. Roentgenogram of chest (anteroposterior view) one month after operation.

It should be recalled that the intrathoracic thyroid masses are practically always of the adenomatous type. Indeed, Lahey (6, 7, 8) and the Criles have repeatedly stated that they had never seen a diffuse goiter (exophthalmic goiter, primary hyperthyroidism) become truly intrathoracic.

The descent of these thyroid masses into the chest is facilitated by a number of factors. These include breathing, swallowing, muscular activity in flexing and rotating the head, nonresistance of the more pliant structures of the thoracic inlet, and gravity. Lahey has described the mechanism of descent of intrathoracic goiters into the mediastinum as follows:

"When an adenoma occurs in thyroid particularly in the isthmus or lower pole of the gland, all the factors are present for propelling that tumor into the superior mediastinum. The adenoma rests above an unobstructed superior thoracic strait bounded in front by the clavicles and sternum and on the sides and back by the vertebrae and first rib. Any discrete tumor arising in the lower pole, covered as it is by the sternohyoid, sternothyroid, and omohyoid muscles, which limit upward extension by their attachments to the hyoid and thyroid cartilage, and which are inserted into the chest wall in front, is subjected to pressure in the downward direction with every act of swallowing."

Clinically, the patients with this lesion fall into one of four groups: (1) those with no symptoms;

(2) those exhibiting signs and symptoms of thyrotoxicosis; (3) those exhibiting pressure symptoms; (4) those with the combination of pressure symptoms and toxicity.

In a relatively large number of patients with good sized intrathoracic goiters there are no symptoms. This is especially true of some of the large masses that expand into the lung fields without producing symptoms of tracheal compression.

The second group requires no comment. In the Cleveland Clinic Series (3), hyperthyroidism was present in 50 per cent of all patients operated upon for intrathoracic goiter. The chief structures involved are the trachea and the great vessels. With tracheal compression the chief clinical manifestations are dyspnea, choking sensations, and stridor. Dilatation of the veins of the upper chest and neck are evidence of compression of the great vessels in the thorax. Cough, dysphagia, changes in the quality of the voice, and hoarseness are rare. The latter occurred in 2 per cent of Crile's cases. The esophagus and recurrent laryngeal nerves are rarely involved. One should suspect a malignant lesion if there is any involvement of the recurrent nerves.

Careful roentgen study of the chest with anteroposterior and lateral views will aid in substantiating the diagnosis. It is especially important to observe movement of the mass on deglutition, under fluoroscopy.

The treatment of intrathoracic goiter is surgical removal. Lahey (6, 7, 8) and Clute (2) have repeatedly stated that it is unnecessary to remove any portion of the bony thoracic wall to facilitate extraction of the large masses. It is much easier to reduce the size of the intrathoracic goiter. The technique is briefly as follows: Intra-tracheal anesthesia is used and the approach is through the usual collar incision. The strap muscles may or may not be divided. The superior pole is secured from above and gentle traction is applied to the upper portion of the mass. With the fingers encompassing the mass gentle, slow dissection is carried out (hugging the capsule) and gradually freeing the goiter. When a good portion of the tumor has been freed, the finger or a hemostat is pushed through the capsule, thus permitting the jelly-like contents to ooze out and making the mass smaller in all diameters. With a little additional gentle traction the thoracic goiter may then be easily delivered. It is surprising to note how little bleeding occurs, especially if one has remained close to the thyroid capsule during the process of finger dissection.

SUMMARY

A case of posterior mediastinal goiter is presented, the 7th recorded instance of this lesion. This thyroid mass was removed from the thorax through the usual collar incision without dividing the neck muscles and without removing any portion of the bony thorax. Attention is directed to the salient etiological and pathological features of large intrathoracic thyroid masses, as well as their important clinical manifestations and diagnostic features. In the surgical removal of these large intrathoracic goiters it is unnecessary to remove any portion of the thoracic cage. Their delivery from within the chest may be facilitated by securing the blood supply from above, careful finger dissection hugging the capsule, combined with steady gentle traction from above and narrowing the transverse diameter of the mass by removing some of the liquid and jelly-like contents.

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A COSMETIC METHOD OF OPERATING UPON VARICOSE VEINS

BOHDAN HEJDUK, M.D., Major, Medical Corps, Czechoslovak Army in Great Britain

IN the past few years there have appeared in medical journals a number of articles pertaining to the treatment of varicose veins. Military surgeons are particularly interested in this treatment because a successful removal of varicose veins substantially improves the physical fitness of the soldier. I would like to call attention to a method which we have employed, since 1927, in many hundreds of cases with very satisfactory results. First of all I want to mention how we developed this method after years of experimenting, and then I shall describe the treatment and point out its advantages.

Since 1924, I have seen, and have also had the opportunity to perform personally, various types of both operative and conservative methods for treatment of varicose veins. Several methods of extirpation have been tried—from the removal of a single varicosity to the extirpation of the entire saphenous vein, this being done by longitudinal, oblique, or curved incision. We have also performed subcutaneous evulsion of the vein by means of Babcock's vein extractor. In a few instances we have tried multiple percutaneous ligation of varicosities; in other cases we limited the procedure merely to the simple ligation of the long saphenous vein in the upper part of the thigh.

Our aim was to obtain the most permanent and at the same time the best cosmetic result. With that aim in mind, we hoped that the method of Klapp would prove successful. This method consists of several subcutaneous discissions of the varicosities after high ligature of the long saphenous vein. From only few skin incisions (3 to 5) the vein is cut subcutaneously by means of a strong tenotome (so called saphenotome). Several radiating discissions (transections) of the varicosities are performed from each wound. Therefore, during the year 1925, we abandoned all other methods, operating exclusively by this method. After some experience we realized that the procedure partially failed to fulfill our expectations. After a retrospective survey of all results, it became apparent that our failures were due to the fact that radiating dissection did not accomplish the result desired; sometimes even long portions of the venous track were not completely severed and consequently the blood was not entirely emptied from the veins. Hematomas appeared often in the subcutaneous tissue and thrombosis developed in the vein from the remaining blood. Subsequently, the thrombolic vein became recanalized and frequently a recurrence of the varicosities appeared.

Therefore, we sought new methods in order to improve the results of operation. At that time, medical literature emphasized the injection treatment. In an attempt to form our own opinion of that procedure, we limited ourselves throughout the year 1926 to use of the injection treatment, reserving operation for only very large varicosities. For the injection, we used various sclerosing solutions recommended in literature at that time, chiefly a 66 per cent solution of glucose. However, the injection treatment alone did not satisfy us. Even when a compression bandage was applied on the extremity immediately after the injection, hard infiltrations formed along the course of the vein, indicating artificial thrombosis. Complete healing sometimes took weeks or even months. In the process of healing, the thrombi became organized due to the entry of the capillaries of the vasa vasorum. New capillaries formed an anastomosis which gradually became dilated in the longitudinal direction thus giving rise to a new venous blood circulation. As the valves of the recanalized vein remained incompetent blood stasis in the vein quickly recurred. We then had to deal with the recurrence of the varicosities. Moreover, the cosmetic effect was far from satisfactory. Blood clots formed in the veins after the injection of the sclerosing solution, became organized, and formed hard fibrous nodules, which were quite visible even through the stockings. The fibrous nodules also caused difficulty during later operations. They could not be removed by subcutaneous discission of the vein only, but required a special skin incision. Furthermore, the cosmetic result after such a procedure, especially in women, is very often unsatisfactory.

In addition, the danger of embolism is to be considered. Delbet, in his comprehensive monograph on varicose veins, did not encounter a single case of embolism in 700 cases of thrombosis venae saphenae, which would seem to exclude the

possibility of embolism arising from vena saphena magna. However, I have seen 2 cases of fatal embolism arising from unligated saphenous veins. In the first case, death occurred the third day after the injection of a strong sclerosing solution into the vein. The injection was performed in an out-patient department of a sanatorium. The second case was observed at our clinic, a patient who had been treated in a conservative manner for thrombophlebitis venae saphenae. Post-mortem findings revealed that death resulted from an embolus which was torn away from a blood clot lodged inside the saphenous vein. After this experience I could not agree with Delbet in his opinion that there is no danger of embolism following the injection treatment.

Therefore, during the later months of 1926, we combined the treatment by injection of glucose with the previous ligation of the saphenous vein in the upper part of the thigh. This was done particularly in cases of large varicosities. But even this combined method did not prove entirely satisfactory. Permanent results were achieved only in about 20 per cent of the cases in which the Brodie-Trendelenburg test was positive before the operation. In the remainder of the cases recurrence became apparent shortly after operation, and the histological findings revealed that this was due to recanalization of the thrombi. Thrombosis occurred because some blood always remained in the vessel in spite of the fact that compression bandages were applied immediately after the injection.

For that reason we considered it advantageous to retain the sclerosing solution in the vein only for a short time so as to produce an irritation of the intima and then, after cutting the entire length of the varicose vein subcutaneously into the shortest possible segments, to expel all blood mixed with the injected solution from the vein so as to prevent any formation of blood clot. For this purpose we considered the best method to be multiple subcutaneous discissions of the saphenous vein, each performed from a separate puncture and followed by expelling all venous content through the small skin apertures. The walls of the vein, after being completely emptied of blood, must be pressed together by bandage so that the intima of one side touches and unites with the intima of the opposite side. Only such immediate union precludes recurrence because the walls of the vein are so closely in contact that the presence of any tissue which could later become recanalized is rendered impossible. The cosmetic result is perfect, as the varicosities disappear completely without any trace and there is no formation of fibrous nodules which can so often be seen after the simple injection treatment. The multiple transections of the vein completely destroy its continuity thus making any future recanalization impossible and thereby securing a permanent result. Furthermore, any sclerosing solution, which may not have been completely expelled through the apertures in the skin and may have remained in the paravenous tissue, can only contribute to a more complete union and obliterate any pieces of vein resulting from previous multiple dissections. For subcutaneous discissions of the veins we now use, instead of a tenotome, a delicate scalpel introduced by Graefe for eye operations. Punctures made by this scalpel are very small and heal completely without leaving scars, thus assuring the cosmetic result of the operation. I have used this combined method from the beginning of 1927 up to date in many hundreds of cases; however, my available records are only from 1927 to 1933 with about 350 cases. My colleagues at the clinic and in other hospitals, who also employed this method, were so satisfied with the immediate and permanent results that they have used it, exclusively, for a number of years.

The operative procedure itself, as well as the postoperative treatment, requires the fulfillment of some principles which I consider to be of utmost importance. After the general examination of the patient preoperatively, we carefully examine both lower extremities for any signs of inflammation. Any purulent process, any inflammation of the veins or lymphatics must be dealt with first and completely healed. Previous thrombosis of the deep veins, even if it occurred many years ago, is a contraindication to a radical operation of superficial varicosities. (Varicose ulcers will be dealt with later.) After thorough cleansing and shaving of the extremities up to Poupart's ligament, the patient is required to stand, so that the varicosities become more visible. All nodular enlargements as well as the venous course are marked on the surface of the skin with a stick of silver nitrate. A cotton applicator is then dipped into a photographic developer and traced along the same areas, thus causing black lines to appear on the skin, thereby indelibly marking all the veins and their tributaries. When the patient puts his weight on the marked extremity, the varicosities become even more prominent. It is recommended that the surgeon prepare the patient himself, as in this way he can ascertain the depth and the location of all the varicosities. This increases the speed and thoroughness of the operative procedure. At

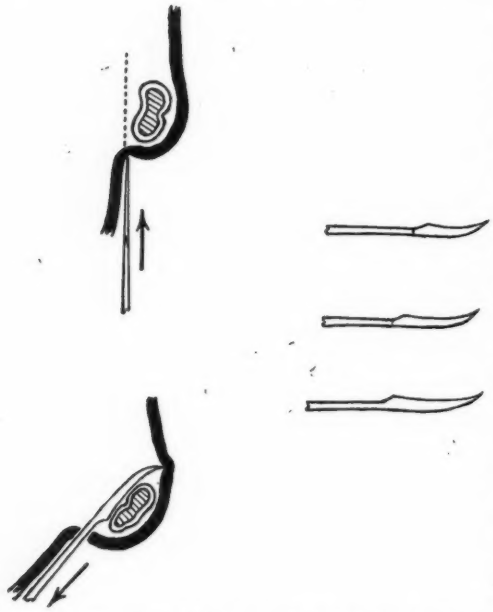

Fig. 1. Diagram showing method of discission of vein.

the same time, we mark the place on the upper part of the thigh where the incision for the saphenous ligation will be made. The course of the vein can most readily be found by means of palpation, when the patient is in a horizontal position, and when his muscles are completely relaxed. This is especially advisable in the cases of women who have a thick layer of subcutaneous fat.

As premedication before the operation, the patient is given an injection of morphine or morphine and scopolamine (hyoscine). The first part of the operation, the ligation of the saphenous vein and the injection of glucose, can be performed under local anesthesia, especially in simultaneous operation on both extremities. The end of the operation is performed under general anesthesia only.

The skin is cleansed with ether and painted with iodine. The sterile sheets and towels are so spread that the operative field is well exposed. The long saphenous vein is ligated through a short incision across the thigh in the direction of the skin ridges. If the course of the vein has been properly marked, an incision about 1 inch in length will usually suffice. The incision is made 2 to 4 inches below the fossa ovalis in order to avoid the inguinal lymphatic glands, which are frequently infected in cases of varicose veins. In former years we searched for the great saphenous vein at its entrance into the fossa ovalis, but it was very often suppurated, due to local infection. The saphenous vein on both sides is isolated, doubly clamped and transected. Its proximal stump is then ligated with catgut and a strong blind cannula is introduced into the peripheral stump and fixed in the vein by means of a small artery forceps and a silk ligature. After that 20 to 40 cubic centimeters of 66 per cent solution of glucose is injected into the vein on either side. After cutting the silk ligature, we remove the cannula and then ligate the peripheral vein with catgut sutures, resecting its remaining free portion as far as possible. The skin is then sutured with fine silk by means of delicate noncutting needles.

Then a general anesthetic is introduced and the subcutaneous discissions of varicosities are commenced. For this purpose, as I have mentioned before, we use Graefe's eye scalpel. The blade of this knife is about ½ to ⅝ inch long and curved at its tip, the shape being similar to a tenotome and the width between 2 and 3 millimeters. After repeated grinding of the blade it becomes even narrower so that the punctures are barely visible. When operating on both extremities we use two scalpels. It is advisable to sharpen the scalpel after each operation. While the scalpel is being sterilized or when stored, the blades are wrapped in cotton for protection.

An assistant elevates the lower extremity of the patient to the level of his own shoulders, thus minimizing bleeding and permitting better access for the surgeon. The scalpel is placed flatly on the skin at a distance of 1/5 to 2/5 inch from the vein. The skin is then pierced at right angles to the course of the vein. We pierce the skin and push the scalpel into the subcutaneous tissue underneath the vein until its point is seen about 1/5 to 2/5 inch on the other side of the vein. Now we rotate the scalpel so that its sharp edge is directed against the vein and skin. We lift the point of the scalpel lightly so that it is visible under the lifted skin and then in one quick movement we cut the vein drawing the knife backward (Fig. 1). Care must be taken not to cut through the skin itself. The discissions are repeated at intervals of 1/5 to 2/5 inch along the entire course of the vein and all its tributaries. The idea is to cut all veins showing varicosities into small segments. Depending upon the extension of the varicose veins, from 50 to 200 of these subcutaneous discissions are usually performed on a single extremity. Care must be taken to avoid cutting

through a tendon, superficial artery, or the peroneal nerve.

It is best to commence the discissions on the upper part of the calf, just below the popliteal groove, continuing toward the foot, because on the elevated extremity the blood flows on the skin toward the thigh, thus leaving clean the next operative field. For this same reason, we cut first the tributaries of the external saphenous vein, leaving until last the internal saphenous vein, where the varicosities are usually largest. Furthermore, to prevent an inflow of blood during this procedure, an assistant grasps firmly the elevated extremity just at the ankles.

When the discissions of all varicosities are finished, the blood is expelled from the veins through the skin apertures by means of pressure and light massage with sterile towels moistened in saline. During this step, which secures complete emptying of the dissected vessels, we progress from the ankle to the knee, applying immediately a sterile compression bandage and making its reverse-turns on the inner side of the leg. As a result of the multiple discissions, only small segments of vessels about $^1/_5$ to $^2/_5$ inch in length remain of the varicosities. Their walls emptied and collapsed, the subcutaneous tissue must be completely pressed together. Care must be taken to prevent hemostasis or ischemia of the leg especially when the bandage is carried above the knee. Sterile cotton is then wrapped around the extremity over the first bandage, or immobilization by splint is used.

After the patient has been put to bed, the legs are slightly elevated to facilitate better blood flow of the deep veins. As soon as the patient has awakened from the effects of the general anesthetic, we test the mobility of the toes and feet, then the sensitivity and discoloration of the skin, to be sure that there is no compression of some nerve or artery. As a rule, during the first, second, and third day after the operation, the toes become slightly swollen, but the swelling soon disappears. The compression bandage and the stitches are removed about the seventh postoperative day. The layer of the dressing, which is in immediate contact with the skin, must be removed with great care in order to avoid tearing off the crusts which have formed over the skin apertures. An ordinary sterile dressing is applied, and the patient is kept in bed 7 to 10 days after the operation. When the extremities have been cleansed with alcohol, the patient is allowed to walk. He is instructed to wear an elastic bandage for another 2 to 4 weeks; this is to be removed at night and worn again in the morning.

COMPLICATIONS

In several instances, we have observed an infection of the wound when the incision had been made at the level of the fossa ovalis. For this reason we now perform the ligation of the great saphenous vein a little lower in order to avoid the lymphatic glands. In 1 case, erysipelas developed from a skin infection which had not completely healed at the time of the operation. Thrombosis of the deep veins occurred in 2 cases, both within 2 or 3 weeks after operation. In one instance it occurred after the classical operation of Klapp.

The most common appearance after the operation is a swelling about the ankles, which developed in about 20 per cent of the patients as soon as they began to walk. In some patients this swelling occurred only occasionally, for instance, in athletes after extensive exercise. The swelling is greatest in the evening and disappears after a night's rest. This phenomenon passes in about 4 to 6 weeks without any intervention. We consider it to be the consequence of too radical a destruction of the superficial venous system. Sufficient time must elapse before the collateral circulation through the deep veins becomes established. This explanation is confirmed by the fact that no swelling occurs after an operation of very large varicose veins where, due to incompetence of the venous valves, a collateral circulation has been established prior to the operation.

RESULTS

The legs, after the operation, are smooth, without any visible fibrous nodules in the subcutaneous tissue. The scar after ligation becomes white in a few months and the punctures are barely noticeable and, if at all, only as tiny whitish dots. Recurrences are very rare. In about 10 per cent of the cases we have observed, after 5 or 10 years, the recurrence of single varicose knots in the course of the tributaries that had not been operated on and sometimes also at the point of an anastomotic communication with the deep venous system. These recurrences can be easily removed under local anesthesia by means of subcutaneous dissection of the nodules with a Graefe scalpel followed by compression bandage for 7 days. Such a procedure can be performed in the out-patient department.

REMARKS

When the femoral portion of the great saphenous vein is enlarged and tortuous, we combine the described operation with subcutaneous removal of this vein by means of Babcock's vein extractor. Counter incision is performed at the

level of the knee. By means of this incision glucose is then injected into the distal veins which are then transected subcutaneously with a Graefe scalpel.

VARICOSE ULCERS

Very satisfactory results have been obtained by our method, even when varicose ulcers have been present. Before the operation, the base of the ulcer is thoroughly cleansed and compresses of Rivanolor Chlumsky's solution are applied for 2 to 3 days in order to sterilize the ulcer and the surrounding tissues.

During the operation the strictest asepsis must be observed. The ulcer is covered with a special towel and, while the saphenous vein is being ligated, very special care is taken to avoid the regional lymph glands which are always enlarged and infected in the presence of varicose ulcers. Therefore, the incision is made 2 to 4 inches below the fossa ovalis. When, after the injection of glucose, the peripheral veins are dissected and the blood is expelled, any contact with the ulcer must be avoided to prevent any contamination. This part of the operation being completed we then take a fresh strong scalpel and make several radiating incisions over the edge and base of the ulcer piercing the skin to the superficial fascia. Silver ointment is immediately applied to the ulcer. Nowadays, of course, sulfa drugs may be administered and a compression bandage put on the extremity. (During the course of the present war, I have had no opportunity to operate upon varicose ulcers but feel sure that sulfa drugs will be of great use.)

The result is very good. The ulcer heals far more quickly than when treated with any conservative method. As soon as the varicosities which cause the venostasis are removed, the nutrition of the skin and subcutaneous tissue is immediately improved. In the postoperative treatment, a dry dressing is applied and packs are avoided. Heliotherapy and application of nonirritating powder are recommended. The healing of the ulcer is permanent. We have never seen a recurrence of ulcers after this type of treatment. Impressed by immediate and permanent results, the professor of dermatology at our university regularly referred to us all cases of varicose ulcers for operative treatment.

THE SULFONAMIDES AS AN ADJUNCT TO THE TREATMENT OF COMPOUND FRACTURES

GEORGE V. FOSTER, M.D., F.A.C.S., Pittsburgh, Pennsylvania

IN 1932 before the Clinical Congress of the American College of Surgeons in St. Louis, I presented a survey of 304 compound fractures of the long bones and their treatment by débridement, Carrel-Dakin technique, and open reduction with plating when indicated. Since then the advent of the sulfa drugs has made advisable a change in the treatment of compound fractures if the case and environment is suitable, and the fracture is seen within a few hours following injury. The importance of the role played by débridement and the sulfonamides has not been accurately established. Caldwell asserts that "the most desirable feature of the drug is obtained through absorption into the blood stream which, from the wound, reaches its peak in 12 to 18 hours and is then ably supplanted by oral administration." Diebert states, "The administration of the sulfonamide group by mouth is relatively unimportant." Keys states that "fractures compound from within, compound fractures produced by rifle or pistol bullets are usually not infected and débridement of such wounds is not necessary." Hook states that "internal fixation and closure of compound wounds is safe in many hands in civil practice but such treatment is strongly discouraged in war surgery. All of the gas gangrene reported following the attack on Oahu occurred in wounds that were primarily closed." Wilson, whose experience with the sulfonamides in compound fractures has mostly been in the war areas, states that "compound fractures incurred under war conditions may be most safely treated by the sulfonamides and the open pack method."

In a large industrial area such as this, with the facilities offered by long and well organized medical and nursing care both in the emergency hospitals in the plants and also in the general hospitals in the city and with heavy industry presenting to us a high percentage of patients with severe compound fractures, we should be able to evaluate correctly each of the constituents which go to make up the proper care of these patients. The factors involved in the correct plan of treatment of such injuries are as follows:

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1. Early and thorough débridement done by a competent, conscientious and painstaking surgeon.

2. Reduction of the fracture with fixation of the fragments by means of internal splints if necessary.

3. The use of the sulfonamides as an adjunct in the treatment of these compound wounds.

Briefly, the outline of treatment is as follows:

1. Débridement. A thorough débridement within 18 hours is still the most essential factor in the treatment of compound fractures. This cannot be overemphasized, the elimination of dirt, crushed and devitalized tissues, foreign bodies, bone fragments without blood supply, is most necessary as the first and most important item in the treatment of these injuries. No amount of sulfonamide or any other kind of drug can take care of a wound left in a dirty condition. The importance of this procedure is shown by the fact that some surgeons have been satisfied to close compound fractures after a débridement done to their satisfaction even before the use of the sulfa drugs.

2. Reduction of the fracture. Following débridement the fracture is reduced, and no hesitation is felt in applying internal fixation in the shape of plates or screws if it is believed that such will more firmly immobilize the fracture and thus promote union. If internal fixation is unnecessary splints are applied, or if the fracture is badly comminuted skeletal traction may be necessary to reduce the fragments satisfactorily.

3. Sulfonamides. The use of sulfanilamide, sulfathiazole, or a mixture of the powder and crystals locally has been carried out in each wound though it was our opinion that its distribution throughout the wound had only a minor influence on the successful outcome of these cases. Two to 5 grams of the drug, however, were spread evenly throughout the wound with care that no lumps were formed that might act as irritating foreign bodies and extrude through the wound at a later date. All wounds were closed without drainage.

Wounds will be met with which are extensively crushed and torn and consequently are swollen and edematous so that primary closure is impossible. These should be carefully débrided, the

Carrel-Dakin treatment instituted, high elevation of the limb carried out, and, the swelling having subsided in 8 to 10 days, secondary closure may be possible. But to attempt complete closure of a swollen engorged limb is to court disaster in the form of infection or gangrene. Extreme swelling is rarely met, however, in the early hours after injury and therefore this procedure is rarely necessary.

The patient having received his initial dose of the drug through the wound, the second dose of 30 grains of sulfathiazole by mouth is given as soon as he recovers from the anesthetic; since pentothal was used in all cases they were usually able to take and retain the drug 8 to 12 hours after operation, and this dosage was given every 4 hours for 2 days. The dosage was then cut in half for 3 days following which 45 grains daily was given until the end of the 8th day when the drug was discontinued. Very little attention was paid to the blood concentration as results just as satisfactory were obtained when the concentration was 3 to 5 milligrams as when the concentration was 10 milligrams per 100 cubic centimeters of blood.

The future treatment of the fracture was carried on in the usual manner. The patient was carefully watched for any unusual temperature reaction; the wound would have been widely opened and the Carrel-Dakin technique instituted on the slightest indication of any infection.

In this series, compound fractures of the fingers, toes, and skull were not included, though their progress was quite satisfactory under treatment by this method. There also were a few cases of fracture of the long bones in which the compound wound was small, usually of the puncture variety, and on admission these were carefully débrided and closed. They were given sulfa drugs by mouth, but if open reduction was required to correct the alinement it was done 7 to 10 days later following our customary method of treatment of a simple fracture. In other words, these cases were transformed into simple fractures and, therefore, their inclusion in this series would only be confusing. In all, 48 compound fractures were treated in 36 individuals: they included fractures of the femur, 1; fractures of radius, 12; fractures of ulna, 10; fractures of tibia, 9; fractures of tarsals and metatarsals, 15; and 1 compound fracture-dislocation of the tarsal bones treated at the Children's Hospital of Pittsburgh.

The acid test of this method came in those cases in which an open reduction was carried out and for proper fixation a foreign material, screw, nail or plate, was applied to the bone and the wound closed over it. There were 14 of these cases. We know that with the molybdenum stainless steel plates and screws the oxidation taking place in the body is far less than with the vanadium or any other metal previously used, yet this factor alone cannot account for the fact that only one plate had to be subsequently removed and this for the reason that it was loose and no sign of infection or oxidation was found at the time of removal.

The benefits of this method of treatment were real and satisfactory.

1. It was possible to close every wound without drainage.
2. Osteitis or osteomyelitis did not develop in any case.
3. Owing to the primary closure of the wound, skin grafting was unnecessary in any case.
4. In fractures near the joints with the wound closed, much earlier and fuller motion could be obtained than in those with the wound open.
5. Dressings of the wound with the consequent contamination which sometimes occurs in open wounds and the loss of valuable time of trained workers was cut to a minimum by the elimination of the open wound.
6. In only one case was a second operation necessary to remove the steel plate. In a previous series by the Carrel-Dakin method, the plate was removed in 68 per cent of the cases.

We are faced with the assertions of experienced competent men such as Hook and Wilson, that the closure of compound fractures has no place in war surgery. On the other hand, packing these compound wounds wide open with various materials does not always lead to the happiest conclusions; even with the Carrel-Dakin method osteomyelitis or osteitis developed in 15 per cent of the cases. To anyone familiar with the treatment of compound fractures this is a tragedy necessitating prolonged disability and frequent operations. Through air transport (3) of the wounded in the service and the giving of plasma en route thousands of severe casualties arrive at modern base hospitals well within an 18 hour period from the time of injury. Well trained surgical personnel is present and the picture is an exact counterpart of that met with in civil life. A distinction cannot therefore be made in the methods of treatment and, should clean surgery done early by competent hands plus sulfa therapy and primary closure of the compound fracture prove more efficient than the open pack method in a wider range of cases, than I have here presented, then undoubtedly this treatment could be carried out in various theaters of war much to the advantage of the injured man.

In conclusion, may I again emphasize that this is a procedure which should be carried out only by the trained surgeon of large experience, by one able to realize the seriousness of a compound fracture and its prolonged disabling qualities if not properly treated, by one sufficiently conscientious and capable of doing a thorough débridement, and with a sufficiently developed sense of judgment to open a wound widely if he believes infection is present.

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A CLINICAL AND LABORATORY EVALUATION OF THE ACTION OF SULFONAMIDE OINTMENTS

JOHN R. COCHRAN, M.D., Chicago, Illinois

HARDLY a day passes that one does not read some new testimony praising the superior qualities of sulfonamides when used locally on burns, open wounds, compound fractures, skin infections. Every drug store, most busy doctors' offices, and dispensaries in hospitals and industry alike use sulfonamides suspended in various ointment bases. The literature and the experience in thousands of cases reported seem almost overwhelmingly in agreement that sulfonamide ointments, used locally, are a real contribution to surgery (3, 5, 8).

The purpose of this article is to report certain clinical and laboratory observations which cast serious doubt on the efficacy of the average sulfonamide ointment.

In 1939 we first started using sulfonamides locally in ointment form. It will be remembered that powdered sulfanilamide was not commercially available at that time. Ointments containing sulfonamides had not, as yet, appeared on the market. Searching for some more effective agent for the treatment of indolent varicose ulcers of the leg, we prepared our own ointment by grinding sulfanilamide tablets in a pharmacist's mortar and mixing this powder in sterile vaseline. It should be noted that at this time we also adopted the principle of applying all such dressings with elastic pressure.

Shortly thereafter, the literature began to give repeated confirmation of our own observations that the ulcers seemed to do better with ointments containing sulfonamides than they had with any other form of local ambulatory treatment. There was a good percentage of cases, however, which failed to do well with sulfonamide ointment therapy.

It was not until 1942 that we began seriously to question the value of the ointments which we had been using. By this time we were using ointments prepared by the pharmaceutical manufacturers. During that year we began a series of controlled clinical experiments for the purpose of evaluating various methods of treating burns. At that time we were also conducting controlled experiments to evaluate the effectiveness of tyrothricin (to be reported elsewhere). In both these experiments controls were set up on each patient so that one area was treated with sulfonamide ointment and another similar injured area was treated with sterile vaseline, tyrothricin, etc. It became obvious that the areas treated with sulfonamide ointments showed clinical infection and positive cultures as often as the control areas treated with sterile vaseline. In fact, it appeared that the areas treated with sterile vaseline healed more rapidly in many cases.

This observation in the clinic led us to a laboratory evaluation of the sulfonamide ointment itself. The particular one we were using at that time was a 5 per cent sulfathiazole ointment in a so called aquaphor base. The laboratory tests we devised were simple, but seemed to us to simulate the contact between ointment and the wound surface. We first suspended a weighed amount of the given ointment in a test tube of normal salt solution and then agitated the mixture. The tube was placed in an incubator at 37 degrees centigrade for 24 hours and was agitated occasionally. At the end of the 24 hour period the chemist made an analysis by the colorimetric method for sulfathiazole in solution. Quite to our surprise we found that there was almost no sulfathiazole in solution. The laboratory reported "a trace," or less than 1 milligram per cent.

Because of this striking result the experiment was repeated with the ointment mentioned and then with a representative sample of most of the commercial ointments available on the market. These ointments were variously described as being in aquaphor base, vaseline, water miscible base, water washable base. The laboratory report in each case was identical. None of the ointments by this method of evaluation liberated any appreciable amount of the drug into the saline.

We then attempted to simulate more accurately the burned surface of a patient by repeating the experiments using human plasma. We also attempted to titrate the amount of free sulfonamide in solution on the burned surface of a patient who had had sulfonamide ointment applied 24 hours previously. The latter method did not give satisfactory results. Gurd, Ackman, and Wilson (5)

From the Division of Surgery, Northwestern University Medical School, and the surgical service of Drs. H. E. Jones and S. W. McArthur, St. Luke's Hospital, Chicago, Illinois.

have performed this experiment to their satisfaction, and results will be reported later in this paper.

Our experiments performed by agitating ointment in human plasma agreed almost exactly with the results in saline, i.e., none of the commercial ointments tested liberated any appreciable amount of sulfonamide drug into the plasma during 24 hours.

Blood concentration tests performed on patients who had had sulfonamide ointment applied to burns almost routinely showed a "trace" only of sulfonamide in the blood stream. (We now believe, from work with a more satisfactory ointment which liberates large amounts of sulfa drugs, that the failure to show any appreciable blood concentration is not the result of the failure of the sulfa drug to go into a solution. It probably results from the well known fact that a burned surface, during the first few days, does not absorb chemicals placed upon it to any appreciable extent.) The observation that blood stream concentration is minimal when sulfonamide ointments are used locally has been confirmed by others, both in burns and on intact skin. (1, 3, 8).

In studying the composition of the ointments we had evaluated, it appeared that the commercial ointments examined at the beginning of 1943 consisted of a suspension of sulfonamides in some more or less oily base. It is well known that a drug suspended in the oily phase stays in that oily phase when water is brought in contact with the ointment (7). One would hardly expect, therefore, that the sulfonamides would be liberated from the oily phase of the ointment when applied locally. If one used an oily base ointment, some additional agent, such as an emulsifying or wetting agent, would have to be added to alter the suspension in such a way that the drug would be liberated into the aqueous phase.

About this time our attention was drawn to the work of Gurd, Ackman, Wilson, and others at the Montreal General Hospital, which appeared to give the answer to an oily base which would still liberate sulfonamides (1, 2, 5). They incorporated a wetting agent, Triethanolamine, in a water and oil mixture. They showed conclusively that the addition of a wetting agent resulted in the liberation of amounts of sulfonamides which approximated the maximum solubility of sulfathiazole in water. We then repeated the laboratory tests we had devised, using the Montreal General Hospital preparation, and discovered the following.

The Montreal General Hospital emulsion mixes very readily with water, saline, or plasma, whereas the usual ointment, even after 24 hours, still is separate from the liquid phase. The Montreal General Hospital emulsion liberates large amounts of the sulfonamide used. When we mixed the Montreal General Hospital sulfathiazole emulsion in saline for 24 hours we were able to recover 40 per cent of the sulfathiazole from the emulsion. Repeating the experiment, using plasma, we recovered 42 milligrams from an original weighed amount of emulsion containing 50 milligrams of sulfathiazole (84 per cent).

Our results indicate a higher solubility of sulfathiazole in the emulsion than the known solubility of sulfathiazole in water (4). It has been shown (5) that sulfathiazole is about 800 times more soluble in the emulsion than it is in water. This solubility undoubtedly results from the use of triethanolamine.

As a result of the tests described we adopted the Montreal General Hospital emulsion as our standard form of sulfathiazole "ointment" therapy. We obtained samples of this emulsion from the Vogel Laboratories, made according to the Montreal General Hospital formula. We also attempted to duplicate the emulsion described in our own pharmacy. Both the preparations seemed much too liquid. It was very difficult to apply this rather watery emulsion to burned surfaces.

For this reason we have modified somewhat the Montreal General Hospital emulsion and the emulsion is now made at the St. Luke's pharmacy according to the formula and directions as follows:

The original Montreal General Hospital emulsion was made on a weight-volume basis, according to the following formula:

	Per cent		Per cent
Sulfathiazole	5	White beeswax	5
Triethanolamine	2	Liquid paraffin	64
Distilled water	24		

Mr. Louis Gdalman at the St. Luke's Pharmacy makes the ointment on the weight-weight basis according to the following formula:

	Per cent		Per cent
Sulfathiazole	5	White beeswax	7.5
Triethanolamine	2	Heavy mineral oil	61.5
Distilled water	24		

In making the ointment, the sulfathiazole, triethanolamine and distilled water are mixed cold. The wax is gently melted, the mineral oil added to the melted wax and this mixture allowed to cool. The oily mixture is then added to the water mixture, with constant whipping. With some experience a smooth, creamy ointment results which has a pleasing odor like vanishing cream. Sterile sulfathiazole crystals, sterile water and oil are used in the preparation of the ointment. Bacteriological tests have shown the ointment to be sterile. This ointment should not be sterilized by heating, since heat will crack the emulsion.

From the practical standpoint of application, the Montreal General Hospital emulsion is most satisfactory. It goes on readily, does not soil clothing or dressings and has considerable anesthetic action. Gurd, Ackman, and Wilson attribute the latter to the sulfathiazole (5).

SUMMARY AND CONCLUSIONS

Clinical as well as laboratory work demonstrates that the majority of present day sulfonamide ointments are inert, liberating inconsequential amounts of sulfonamides. Whatever value they possess is contained in the ointment base and not in the sulfonamide. An effective ointment is described, originally elaborated at the Montreal General Hospital, which liberates large amounts of sulfonamides.

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ORGANIZATION OF THE RED ARMY MEDICAL CORPS

A GREAT deal has been written in the lay press about the excellent results of the treatment of war injuries by the surgeons in the Soviet Union. Perhaps as a result of the lay reporter's tendency to embellish the telling of surgical facts, the impression is rather widespread that Russian surgical practice and technique are far advanced beyond that practiced in the United States or Great Britain. As a matter of fact, there is much to be admired in Russian surgery; but the surgical principles recognized by well trained surgeons, of whatever country they may be, remain essentially the same. The technique of applying those principles differs between countries, clinics, and men; but taken as a whole, the character of graduate surgical training in the United States has produced in the last twenty-five years a generation of surgeons whose technical ability is difficult to surpass. The Surgeon General of the United States Army has said it is these men, and not adjuvant methods of treatment, who are responsible for the high quality of the results obtained in the treatment of the casualties which have occurred in World War II.

Very little attention has been paid to other accomplishments of Soviet surgeons and this is true, particularly, in the field of military medical organization for the care of the wounded. Diagrams of the medical organization in the Red Army have been published, but to see it in practice serves to emphasize its vertical character. The Surgeon General of the Red Army, Yefim Ivanovich Smirnov, who is 38 years of age, is responsible directly to the Peoples' Commissariat for Defense and the Chief of Staff of the Army. There is no intermediary organization between him and the Chief of Staff; and this direct relationship enables him to be entirely aware of the nature, purpose, and magnitude of each offensive before it is launched. His responsibility is to provide adequate medical care, equipment, and hospitalization for anticipated casualties. Under his direct supervision, the ranking medical officers of his corps assigned to the air, ground, and support forces carry out the policies of medical or surgical treatment laid down by him. Wounded airmen are treated in the same hospitals and by the same surgeons as are injured infantrymen. A compound fractured femur received by a pilot or gunner is treated according to the same surgical principles and under the same environment as one received by an infantryman as the result of an exploding ground mine. There is no apparent need in the Red Army Medical Corps to have a separate group of doctors, hospitals, and nurses for the treatment of the air force per-

sonnel. While the medical organization within an Army must be under the command of the general of that Army for tactical combat purposes, the policies of surgical treatment are uniform and are under the control of the Surgeon General. In name and in fact, then, Smirnov is the Surgeon General of the Red Army, and the resulting unity of action in the care of the wounded is therefore speedy and effective.

Of course, such an organization of a medical corps is not new. Until General Order No. 31 was issued on February 18, 1918, the relationship of the Chief Surgeon of the American Expeditionary Force in World War I to the General Staff and the chiefs of the Administrative Staffs was similar to that which existed between the Surgeon General's Office, the General Staff, and the several bureaus of the War Department situated in Washington. Both were identical in relationship to that which now exists between the Surgeon General of the Red Army and its General Staff. But, on that date and during the middle of a War, the Chief Surgeon was given a dual rôle in the Services of Supply and as an advisor to the General Staff, but he was situated at the headquarters of the Services of Supply. It became obvious almost immediately that this order made the Chief Surgeon's Office merely an agency for the procurement and distribution of supplies and personnel and had the effect of separating him, both physically and functionally, from the activities of the Zone of Operations. It became evident, also, that the Medical Department was handicapped in its extensive and complex operations by being cut off from direct access to the Chief of Staff by a line of command. This transfer of the Chief Surgeon's office in the American Expeditionary Force to the Services of Supply was effective for the procurement of supplies and the construction of hospitals, but according to a letter written on March 15, 1918, by the Chief Surgeon, it resulted in disconnection of his office from the medical administration of the front. It was impossible for the Chief Surgeon to meet his responsibility for the conduct of medical affairs in the combat zone and caused his relations with the combat forces virtually to cease.

The Chief Surgeon of the American Expeditionary Force at that time made a strenuous written presentation of his views. He said in various memoranda:

"The present organization in the American Expeditionary Forces places a line officer of the General Staff in position to pass upon or present for higher consideration all matters of fundamental policy affecting the Medical Department. He can nullify the most carefully worked out program having for its object Medical Department efficiency."

Again: "In providing the necessary medical supplies for an army, only one of the comparatively unimportant functions of the Medical Department has been fulfilled. The demands made upon the Medical Department by combat activities cannot be satisfied if the prevailing conception of that department as a supply department is adhered to."

Following World War I this organization of the Surgeon General's Office under the Services of Supply, or Army Service Force, was continued. During peace time the classification of the Medical Department among the supply services was emphasized to the detriment of the equally or more important staff function. The subordinate position of the Surgeon General necessitates the approval of nonmedical line officers of the Army Service Forces before purely technical medical regulations can be put into effect. For example, the Surgeon General had long desired to authorize and direct immunization against tetanus. This

matter was held up for more than a year pending the approval of line officers and was cleared barely in time to protect our present Army against this infection.

Another of the results of this type of organization has been the gradual development of a medical corps in the Air Force based on the erroneous assumption that injuries received from combat in the air require separate hospitals and staffs for their treatment. It is well recognized that there has been and is now a strong and vigorous campaign for an Air Force Medical Corps quite separate and distinct from the Medical Department of the Army.

Much the same situation exists in regard to medical facilities in connection with the ground forces. Each Army has its surgeon whose policies of treatment cannot be influenced by direct command from the Chief Surgeon of a theatre of operations. In fact, in the United States surgical consultants for Service Commands are unable to examine casualties which have been sent to an Evacuation Hospital, situated in the area of that Command but on maneuvers with the Army to which it was attached, until permission is obtained through the line of command. In a theatre of operations, the activities of the consultants to the surgeon of the theatre are confined to station and general hospitals directly under his command. Consequently, an Army or an Air Force may have consultants duplicating in number and function those attached to the staff of the Theatre Surgeon. There are, therefore, air force, ground force, and service force chief surgeons, independent in practice, but on paper the first two subordinate to the latter, who has the title of Surgeon General of the U. S. Army, or Chief Surgeon of a Theatre of Operations, as the case may be. On the surface it would appear that even more confusion has been added by the appointment of a Chief Medical Officer to the Supreme Headquarters of the Allied Expeditionary Forces.

The position of the Medical Department and the Surgeon General in the Staff organization of the Army makes it incumbent upon the Surgeon General to have an enormous reservoir of supplies, equipment, and doctors to meet any demand which may be made upon him without an opportunity for him to be acquainted with the details of a planned campaign or battle. That such a situation must inevitably lead to inactivity of doctors while they wait for their removal from the supply shelf for use and that it is natural to overstock for fear of being short of the demand at any given time is obvious. To say the least, it is an extravagant use of doctors which is more serious than the overstocking of supplies or equipment.

In all fairness it must be said that as a group civilian surgeons were not interested in the affairs of the Medical Corps of the U. S. Army in the 25 years intervening between World Wars I and II. They universally recognized the errors in organization of the Medical Department committed in World War I, but upon their return home they were anxious to forget the tribulations of war and eager to resume their professional lives. The civilian surgical organizations made no attempt to learn of the problems and plans of the Medical Department in case of war, though a few surgeons who had participated in World War I had shown an individual interest to help which was consistently rebuffed. Yet the civilian doctors have had to shoulder the load of work during this war with a nucleus of less than 2,000 Army doctors, who as a group adopt a defensive attitude of passive resistance toward the newly commissioned medical officer.

Finally, any criticism of the attitude of the Medical Department toward postgraduate

surgical training, medical educational policies, insistence upon the adoption of measures which might prevent certain injuries of war, or the extravagant use of doctors in the Army, should not be directed at the Surgeon General of the U. S. Army or his staff. The fault lies in the fundamental anomalous relation of his office to the General Staff and the Army as a whole, which can be corrected only by the War Department.

LOYAL DAVIS

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

IN his book *The Foot*[1] Norman C. Lake deals with disorders, injuries, wounds, infections, and vascular disease of the foot. The fact that this is the third edition of the book published since 1935 indicates that it has found wide recognition from those interested in disorders of the foot. A careful review of its contents leaves the impression that its popularity is justified.

The section dealing with the evolution of the foot, the influence which evolutionary changes have had upon the production of foot disorders, and the development of the foot, is excellent; and the deductions made are sound if not final. Although most worthwhile, the material on evolution and development is perhaps too exhaustive for a book of this type since it comprises about 10 per cent of the entire subject matter. The same criticism may be made of the section on footwear which includes an interesting but not particularly informative historical chapter.

The discussion of foot disorders in general is thorough and informative. However, the material dealing with fractures and wounds of the foot and congenital club foot is not impressive and leaves much to be desired. It is questionable whether such a superficial discussion of these subjects as is given has any place in a book of this type which is primarily concerned with static and circulatory foot conditions. On the other hand, the discussion of vasospastic lesions, trench foot, frostbite, and immersion foot is particularly good and is based on the latest information to be had on these subjects; all are covered in a most complete and interesting manner.

Mr. Lake has written a scholarly book in which the contributing and exciting causes of foot disorders are thoroughly covered, and the pathology of the various subjects completely and lucidly discussed. Its chief weakness from the point of view of the clinician lies in its lack of definite recommendations for treatment, a tendency to rely upon and advise conservative measures, which are only palliative and rarely prove satisfactory, and a failure to provide a section dealing adequately with the surgical operations which are useful in correcting foot pathology and give satisfactory and permanent results.

On the whole, this book is decidedly worthwhile, and its reading will repay anyone who is interested in the treatment of foot disorders.

FRANK D. DICKSON

[1]The Foot. By Norman C. Lake, M.D., M.S., D.Sc.(Lond.), F.R.C.S. (Eng.). 3d ed. Baltimore: The William & Wilkins Co., 1943.

AS the book *Traumatic Injuries of the Facial Bones*[2] is a new departure in method of presentation, direct quotations from it may be most descriptive.

"The plan of this book has been based on many requests from officers of the armed forces who have been assigned to the Mayo Foundation for training in maxillofacial surgery. These officers have urged Dr. Erich and Dr. Austin to publish their demonstrations of methods of dealing with fractures of the bones of the face. In doing so, the authors have given proper emphasis to the fact that many facial injuries involve structures in the repair of which the dental surgeon may well be concerned.

"The material is a collection of procedures, which at the Mayo Clinic, have given the most satisfactory results with the fewest complications."

This book is divided "not only into chapters but also into individual problems, under each of which the management of specific types of injuries of the facial bones is considered." The problems are divided into "comments" and detailed discussions, with reading material opposite the illustrations.

"The reader will find considerable repetition. This is intentional to stress those items which deserve emphasis. Moreover, this volume was not designed to be read necessarily from cover to cover, instead it has been prepared as a handbook, in a manner that, we hope, will enable the reader to obtain the essential information concerning each problem without perusal of an entire chapter or the complete book."

The basis of most of the illustrations are moulages by Dr. A. H. Bulbulian that have been familiar in exhibits at medical meetings. On these moulages have been mounted the various appliances recommended.

As it is the definite task of the authors in presenting their own material, the reader may be spared making comparisons with any divergent idea or methods. The authors are generally conservative; and though at first glance the procedures may seem complicated, the number of them is actually limited. There have been so many varieties of apparatus and so many methods proposed for fixation that priorities are difficult to establish, and the authors have perhaps made easier reading by not calling attention to the history and development of every fundamental. The addition of clinical photographs and results would be of great value, but collection of

[2]Traumatic Injuries of Facial Bones; an Atlas of Treatment. By John B. Erich, M.S., D.D.S., M.D., and Louie T. Austin, D.D.S., F.A.C.D., in collaboration with Bureau of Medicine and Surgery U. S. Navy. Philadelphia and London: W. B. Saunders Co., 1944.

them would be a colossal task and would add much to the length of the volume.

The presentation is straightforward; the editing is excellent; and the book will be gladly received by all who are interested in the work it describes.

JAMES BARRETT BROWN

THE third edition of *Clinical Laboratory Methods and Diagnosis*,[1] which first appeared in 1935, has been partially rewritten, and so much material on newer laboratory tests and interpretations has been added that it is printed in 2 volumes, totaling 2130 pages. A 100 page complete index is added in each volume, a feature which greatly enhances the usefulness of this encyclopedic work.

All fields of laboratory work are treated with informal arrangement of clinical manifestations of disease, related laboratory procedures in complete detail, the interpretations of the results, author's comments, and bibliography. In many chapters aspects of particular interest are elaborated, controversial evidence is presented, and illustrative case histories are given. In addition to adequate and detailed discussion of the usual clinical laboratory tests, there are included chapters on postmortem examinations, tissue cutting and staining, preparation of museum specimens, toxicologic technic, detection of crime by laboratory methods, and minimal supplies, equipment and reagents for patholgic laboratories.

These two volumes bring together a great mass of information of general medical, as well as of special technical, interest. The previous editions have had general acceptance. The present greatly enlarged edition will be found of value as a laboratory guide, general medical treatise, and a ready reference for many esoteric subjects related to laboratory practice and not usually found in laboratory manuals.

JOHN C. MCCARTER

IN *An Atlas of Anatomy*[2], consisting of 183 pages and 232 illustrations, 105 pages are allotted to the head and neck, 43 to the thorax, and 33 to the vertebrae and vertebral column. The subject matter is well indexed, and illustrations are listed.

Volume 2 has the same general appearance as Volume 1. Clarity without cluttering is achieved by judicious placing of the illustrations on the page. Simplification in labeling plus meticulous accuracy of the plates all enhance the teaching value of this book. Depth or 3rd dimension is constantly emphasized. For example, plates 286 and 287 on the right and left sides of the mediastinum, respectively, not only are artistically beautiful but also are anatomical treasures. They show the thoracic cage with its muscles and bones, the diaphragm, pleura and lungs, sympathetic trunks, phrenic and vagus nerves, arteries and veins, bronchi and major blood vessels. all easily visualized with perfect inter-relationship,

Mastery of anatomic detail is made possible to the student only by carefully planned dissections. Thus there are four plates on the posterior triangle of the neck. These start with the superficial structures and end with the brachial plexus and subclavian vessels illustrating surgical anatomy as it is encountered either in the dissecting room or operating amphitheater. The dissections of the skull are also novel and valuable. For example, the interior of the base of the skull, illustration 361, shows both temporal bones removed; but the heads of the mandible are *in situ*. This plate makes it possible to see the base of the skull and still look through it. Specialties are not neglected. The pharynx, palate, teeth, nose, ear, and eye are included.

The one possible criticism rests in the arrangement of the plates. It was somewhat disconcerting to find the posterior triangle separated from the anterior triangle of the neck by illustrations of the skull, midbrain, and eye.

By utilizing original, well planned dissections and remarkable clarity in his photographic plates, Grant has prepared an atlas which will simplify and facilitate the teaching of surgical anatomy.

SAMUEL J. FOGELSON

IN the foreword to the book *The Permeability of Natural Membranes*[3], Professor Harvey, points out that "organisms could not have evolved without relatively impermeable membranes to surround the cell constituents." And again, "no one can fail to be impressed with the great difference in properties of living and dead cells. The dead are completely permeable to diffusible substances, while the living retain one material and pass another." Around this theme, Dr. Davson and Dr. Danielli have built a book of 21 chapters (361 pages), in which they have assembled and critically analyzed existing data of vital importance to the cell physiologist, the neurologist, and the clinician who seeks a mechanistic answer to problems of cell permeability, absorption and secretion, and changes in ion distribution accompanying nerve conduction and muscle contraction.

Methods employed in measuring ionic equilibrium are discussed and the necessary mathematical formulation given. The nature of the plasma membrane of the erythrocyte is explained. It is thought to consist of a lipoid film, a few molecules in thickness, to which is absorbed polypeptide chains of protein oriented with respect to polar and nonpolar groups. The structural solidity is postulated as possibly being due to a crosslinked meshwork of the polypeptide chains resulting from the unfolding of the adsorbed protein molecules on the cell surface. Such a structure might account for the sieve-like properties observed in some cell membranes. Studies

[1]Clinical Laboratory Methods and Diagnosis; A Textbook on Laboratory Procedures With Their Interpretation. By R. B. H. Gradwohl, M.D., D.Sc. 3d ed. Vols. 1 and 2. St. Louis: The C. V. Mosby Co., 1943.

[2]An Atlas of Anatomy; In Two Volumes. By J. C. Boileau Grant, M.C., M.B., Ch.B., F.R.C.S.(Edin.). Vol. 2: Vertebrae and Vertebral Column, Thorax, Head, and Neck. Baltimore: The Williams and Wilkins Co., 1943.

[3]The Permeability of Natural Membranes. By Hugh Davson, D.Sc., and James Frederic Danielli, D.Sc., A.I.C. With a foreword by E. Newton Harvey. Cambridge: University Press; New York: The Macmillan Co., 1943.

concerning the permeability of the erythrocyte are most complete.

Even the casual reader cannot help but retain certain facts which contrast with his usually accepted opinions. To mention but two instances; the "chloride shift" usually associated with the name of Hamburger, was discovered by Nasse in 1878. Hamburger rediscovered this phenomenon in 1891. The second point concerns the potassium or sodium content of the erythrocyte. In man, rabbit, monkey, pig, and some other species the potassium concentration is approximately 100 millimols per 1000 grams, sodium being 16 millimols or less. In the erythrocyte of the dog and cat, however, conditions are reversed, the sodium concentration is 107 and 104 millimols per 1000 grams for the respective species, with a potassium concentration of 9 millimols or less.

Electrical phenomena associated with ionic distribution across a membrane are amply discussed. During the passage of an impulse in a nerve, or contraction in a muscle, the resting potential falls. This seems to be associated with a transitory change in membrane permeability permitting a leak of K^+ from the membrane cells.

Hemolysis is discussed from the standpoint of hypotonicity and lysis. Hypotonic hemolysis may result in (a) the cell being ruptured into a number of fragments, or (b) the cell membrane stretched so that existing pores are enlarged sufficiently to allow the passage of hemoglobin, or (c) the cell membrane breaks with one or more large holes appearing. From electrical impedance studies of "ghosts" evidence favors the third alternative.

The chapter on secretion considers among other things the phosphorylation of glucose during absorption from the intestine or from the glomerular filtrate by the proximal convoluted tubule of the kidney. In either case the mechanism postulates that glucose passing into the cell membrane is converted to the glucose-phosphate ester which cannot diffuse back through the membrane of the cell by which it entered. It then passes through a second membrane into body fluids being again converted to sugar by an enzyme associated with this cell membrane. Diagrams amply illustrate the discussion. The secretion of glucose requires energy for phosphorylation which is supplied by the metabolism of the cells of the first membrane. The authors state that "this type of active transport is available for all substances which, on penetration into a cell, are easily synthesized into a substance whose rate of back diffusions through the cell membrane is less than that of the original substance."

The chapter on the kidney summarizes the modern concepts of glomarular filtration and tubular absorption. The evidence for tubular secretion of phenol red and creatinine in man is cited. Varying tubular activity in other species is discussed.

This book presents a wealth of material in a very able manner. The literature is critically evaluated. Opinions, which in the authors' judgments are inadequately supported by fact, are disposed of with finality. An extensive bibliography follows most chapters. The appearance of this book is timely and should facilitate research in one of the most fundamental fields of physiology.

CHESTER J. FARMER

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

INFECTIONS OF THE PERITONEUM. By Bernhard Steinberg, M.D. With a Foreword by Frederick A. Coller, M.S., M.D. New York and London: Paul B. Hoeber, Inc., 1944.

CÆSAREAN SECTION; THE HISTORY AND DEVELOPMENT OF THE OPERATION FROM EARLIEST TIMES. By J. H. Young, M.B., Ch.B., D.T.M. & H.(Edin.). With a Foreword by Miles H. Phillips, M.D.(Hon.), B.S., F.R.C.S., F.R.C.O.G. London: H. K. Lewis & Co., Ltd., 1944.

PRINCIPLES AND PRACTICES OF INHALATIONAL THERAPY. By Alvan L. Barach, M.D. Philadelphia, London, Montreal: J. B. Lippincott Company, 1944.

PHYSICAL MEDICINE IN GENERAL PRACTICE. By William Bierman, M.D. New York and London: Paul B. Hoeber, Inc., 1944.

THE PRINCIPLES AND PRACTICE OF OPHTHALMIC SURGERY. By Edmund B. Spaeth, M.D. 3d ed. Philadelphia: Lea & Febiger, 1944.

SECRETORY MECHANISM OF THE DIGESTIVE GLANDS. By B. P. Babkin, M.D., D.Sc., LL.D. New York and London: Paul B. Hoeber, Inc., 1944.

THE NEUROSURGICAL PATIENT. By Carl W. Rand, M.D. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1944.

THE PATHOGENESIS OF TUBERCULOSIS. By Arnold R. Rich, M.D. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1944.

THE SYMPTOMATIC DIAGNOSIS AND TREATMENT OF GYNAECOLOGICAL DISORDERS. By Margaret Moore White, M.D. With a Foreword by F. J. Browne, M.D. London: H. K. Lewis & Co., Ltd., 1944.

UROLOGICAL SURGERY. By Austin Ingram Dodson, M.D. St. Louis: The C. V. Mosby Co., 1944.

FERTILITY IN MEN; A CLINICAL STUDY OF THE CAUSES, DIAGNOSIS AND TREATMENT OF IMPAIRED FERTILITY IN MEN. By Robert Sherman Hotchkiss, B.S., M.D. With a Foreword by Nicholson J. Eastman, M.D. Philadelphia, London, Montreal: J. B. Lippincott Co., 1944.

FERTILITY IN WOMEN; CAUSES, DIAGNOSIS AND TREATMENT OF IMPAIRED FERTILITY. By Samuel L. Siegler, M.D., F.A.C.S. With Foreword by Robert Latou Dickinson, M.D. Philadelphia, London, Montreal: J. B. Lippincott Co., 1944.

CATARACT AND ANOMALIES OF THE LENS; GROWTH, STRUCTURE, COMPOSITION, METABOLISM, DISORDERS AND TREATMENT OF THE CRYSTALLINE LENS; By John G.

Bellows, M.D., Ph.D. St. Louis: The C. V. Mosby Co., 1944.

TECHNIC OF ELECTROTHERAPY AND ITS PHYSICAL AND PHYSIOLOGICAL BASIS. By Stafford L. Osborne, M.S., Ph.D., and Harold J. Holmquest, B.S., B.S. (M.E.). Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1944.

HYPERTENSION AND HYPERTENSIVE DISEASE. By William Goldring, M.D., and Herbert Chasis, M.D. New York: The Commonwealth Fund, 1944.

TUBERCULOSIS OF THE EAR, NOSE, AND THROAT; INCLUDING THE LARYNX, THE TRACHEA, AND THE BRONCHI. By Mervin C. Myerson, M.D., Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1944.

TEXTBOOK OF GYNECOLOGY. By Emil Novak, M.D., F.A.C.S. 2d ed. Baltimore: The Williams & Wilkins Co., 1944.

CLINICAL UROLOGY. By Oswald Swinney Lowsley, A.B., M.D., F.A.C.S., and Thomas Joseph Kirwin, M.A., M.S., M.D., F.A.C.S. Vols. 1 and 2. 2d ed. Baltimore, Md.: The Williams & Wilkins Co., 1944.

INTRAVENOUS ANESTHESIA. By R. Charles Adams, M.D., C.M., M.S.(Anes.). New York and London: Paul B. Hoeber, Inc., 1944.

THE AMERICAN ILLUSTRATED MEDICAL DICTIONARY; A COMPLETE DICTIONARY OF THE TERMS USED IN MEDICINE, SURGERY, DENTISTRY, PHARMACY, CHEMISTRY, NURSING, VETERINARY SCIENCE, BIOLOGY, MEDICAL BIOGRAPHY, ETC., WITH THE PRONUNCIATION, DERIVATION, AND DEFINITION. By W. A. Newman Dorland, A.M., M.D., F.A.C.S. 20th ed. Philadelphia and London: W. B. Saunders Co., 1944.

MINOR SURGERY. Edited by Humphry Rolleston and Alan Moncrieff. New York: Philosophical Library, 1944.

MODERN MEDICINE ANNUAL—1943. Minneapolis, Minn.: Modern Medicine, 1944.

TECHNIQUE IN TRAUMA; PLANNED TIMING IN THE TREATMENT OF WOUNDS INCLUDING BURNS. By Fraser B. Gurd, M.D., C.M., and F. Douglas Ackman, M.D., C.M., in collaboration with John W. Gerrie, M.D., C.M., Joseph E. Pritchard, M.D., Edward S. Mills, M.D., C.M., and Frederick Smith, M.D. Preface by John S. Lockwood, M.D., Commentary by Ralph R. Fitzgerald, M.D., C.M. Philadelphia, London, and Montreal: J. B. Lippincott Co., 1944.

THE DENTAL TREATMENT OF MAXILLO-FACIAL INJURIES; WITH SUPPLEMENTARY MATERIAL ON CASES AND TECHNIQUES. By W. Kelsey Fry, M.C., M.R.C.S., L.R.C.P., L.D.S., R.C.S.(Eng.), P. Rae Shepherd, L.D.S., R.C.S. (Eng.), Alan C. McLeod, D.D.S.(Penn.), B.Sc.(Dent.), Toronto, L.D.S., R.C.S.(Eng.), and Gilbert J. Parfitt, M.R.C.S., L.R.C.P., L.D.S., R.C.S.(Eng.). With Foreword by Professor F. R. Fraser, M.D., F.R.C.P., and a Section on Fractures of the Middle Third of the Face by A. H. McIndoe, M.S., F.R.C.S., F.A.C.S. Philadelphia and Montreal: J. B. Lippincott Co., 1944.

THE TREATMENT OF PEPTIC ULCER; BASED UPON TEN YEARS' EXPERIENCE AT THE NEW YORK HOSPITAL. By George J. Heuer, M.D., assisted by Cranston Holman, M.D., and William A. Cooper, M.D. Philadelphia, London, and Montreal: J. B. Lippincott Co., 1944.

CANCER PRIMITIVO DEL PULMON; ESTUDIO CLINICO QUIRURGICO. By Ernesto Escudero. Buenos Aires: Libreria Hachette S.A., 1943.

HYDRONEPHROSIS AND PYELITIS (PYELONEPHRITIS) OF PREGNANCY; ETIOLOGY AND PATHOGENESIS; AN HISTORICAL REVIEW. By H. E. Robertson, M.D. Philadelphia and London: W. B. Saunders Co., 1944.

NEW AND NONOFFICIAL REMEDIES, 1944. CONTAINING DESCRIPTIONS OF THE ARTICLES WHICH STAND ACCEPTED BY THE COUNCIL ON PHARMACY AND CHEMISTRY OF THE AMERICAN MEDICAL ASSOCIATION ON JANUARY 1, 1944. Chicago: American Medical Association, 1944.

COUNCIL ON PHARMACY AND CHEMISTRY OF THE AMERICAN MEDICAL ASSOCIATION FOR 1943 WITH THE COMMENTS THAT HAVE APPEARED IN THE JOURNAL. Chicago: American Medical Association, 1944.